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CONTENTS

		Page
EDUCATION IN ITS RELATION TO AGRICULTURE	*Bernard Coventry, C.I.E.* ...	1
THE APPLICATION OF BOTANICAL SCIENCE TO AGRICULTURE	*Albert Howard, C.I.E., M.A.* ...	14
IMPORTANCE OF SOIL-AERATION IN FORESTRY	*R. S. Hole, F.C.H., F.L.S., F.E.S.* ...	27
THE RE-ALIGNMENT OF AGRICULTURAL HOLDINGS	*B. C. Burt, B.Sc.*	33
SCIENTIFIC METHODS IN AGRICULTURAL EXPERIMENTS	*A. C. Dobbs* ...	40
THE IMPORTANCE OF SOIL VENTILATION ON THE ALLUVIUM	*Albert Howard, C.I.E., M.A.* ...	46
THE DYEING VALUES OF SOME INDIGENOUS DYE-STUFFS	*J. P. Srivastava, M.Sc. Tech., Assoc. M.S.T.* ...	53
THE AQUATIC WEEDS OF THE GODAVARI AND PRAVARA CANALS OF THE BOMBAY PRESIDENCY—A PROBLEM IN APPLIED ECOLOGY...	*W. Burns, D.Sc.*	65
IRRITABILITY OF THE BLADDERS IN *Utricularia*	*T. Ekambaram, M.A., L.T.* ...	72
MODELS TO ILLUSTRATE SEGREGATION AND COMBINATION OF MENDELIAN CHARACTERS...	*H. M. Chibber, M.A.* ...	80
THE CORRELATION OF RAINFALL AND THE SUCCEEDING CROPS WITH SPECIAL REFERENCE TO THE PUNJAB	*S. M. Jacob, I.C.S.*	86

BUREAU OF ECONOMIC BOTANY, GOVERNMENT BOTANICAL GARDENS, ✻ LAL-BAGH, BANGALORE. ✻
AUG 17 1916

PREFACE.

THE Third Indian Science Congress held at Lucknow in February 1916, was a great improvement on the first and second meetings, and the expectations of the promoters as to the advantages of such meetings were on this occasion shown to be justified. The Indian departmental system of Government is apt to restrict correspondence between members of its numerous scientific departments and public and private institutions and to create a state of water-tight compartments. This is a serious drawback to the interests of scientific progress in a country where most of the scientific work is carried on under the auspices of Government. A Science Congress breaks down these barriers and brings together men of varied shades of opinion in every branch of scientific activity, and enables them to check and discuss problems in a manner for which the ordinary Government reports and publications offer no corresponding facilities. It also aids in the sifting of the good from the bad and gives the public, which is none too well informed on scientific matters, an opportunity of becoming acquainted with the doings of science. For these reasons the Indian Science Congress would seem to deserve every encouragement. It is hoped that it will continue to improve and become a powerful weapon for the aid and advancement of scientific progress in India.

One of the features of the last Congress was the creation of an Agricultural Section in which papers related to problems affecting the agricultural industry were read and discussed. Some of these are of considerable interest, and it is thought that to bring out a selection in the form of a Special Congress Number of the Agricultural Journal of India will be appreciated by the readers of the Journal. This explains the reasons for the present issue.

INDORE:
Dated the 5th May, 1916.

BERNARD COVENTRY.

With acknowledgments to the Asiatic Society of Bengal, under whose auspices the Indian Science Congress was held, for their kindness in allowing us to publish the papers contained in this number *in extenso.*

EDUCATION IN ITS RELATION TO AGRICULTURE.

BY

BERNARD COVENTRY, C.I.E.,

Late Agricultural Adviser to the Government of India and Director of the Pusa Agricultural Research Institute.

" I am no educator, no teacher ; I have made no psychological study of young people from an educational point of view, nor of the different methods of teaching suited to different ages, no statistical investigation of the influence of particular curricula in training the mind or furnishing it with useful information. I have, in short, neither made contributions to the science of education nor practised the art ....I can speak only as a member of the general public—not as an expert...............not that I regard the view of the general public as unimportant................ The general public must, as all will admit, decide what is to be spent on education or, more strictly, on schools and colleges and professional educators, out of both public and private income—it is for them to decide on its relation to other social and family needs. But the concern of the public with education is not merely financial and administrative. It is more intimate than that. For education is not a subject like physics or chemistry on which only an expert has a right to an independent view. There are, no doubt, aspects of it of which only the expert can properly judge, there are experiments in it which only the expert can advantageously try, and there are, of course, departments of it in which the opinion of the expert is indispensable. But without depreciating either the science and art of education, it is clear that when we take education in its widest sense it concerns everybody and almost everybody is bound to have views about it."

These words were spoken by no less a person than Mrs. Henry Sidgwick in her address as President of the Section on Educational Science at the recent meeting of the British Association at Manchester.

I feel like Mrs. Sidgwick that I am " no educator and no teacher " and that an apology or at least an explanation is required from me for troubling you to-day in a subject on which I am not an expert. But when we have it on such an authority as Mrs. Sidgwick that education " concerns everybody and almost everybody is bound to have views about it " I feel I have a measure of sanction for imposing my views upon you. I do not propose, however, to make full use of this sanction and tell you all I think about education, but I propose to restrict my remarks to education in its relation to agriculture and further with the exception of an introductory statement dealing with a few facts, I do not propose to say much on the education of youth, but of that of the adult. You will probably all admit that this is quite a novel and peculiar way of dealing with the question of education, but I trust you will find it none the less interesting and instructive. I should like to say before I go any further that I claim no credit for the ideas I shall place before you. They all come from America and, like everything that comes from that wonderful country, they are exceedingly " cute " and practical and in my opinion are eminently applicable to India.

The population of British India comprises over 255 million souls. Of this vast multitude 80 per cent. or over 200 millions, that is to say, 4 in every 5 are dependent on agriculture. Any educational system therefore which does not take into consideration the relationship it should bear to agriculture is likely to be at a disadvantage. It is on the importance of this aspect of the educational problem I intend to address my remarks. Now out of the whole population, 7½ millions or about 3 per cent. are scholars, though 15 per cent. or 36 millions are of the school-going age. Thus only 20 per cent. of those of the school-going age receive any education at all. Of these 7½ million scholars, about 1 million proceed to secondary education and about 40,000 reach a University career.

In judging of these figures in relation to the agricultural industry it should be borne in mind that the percentage of scholars is much higher in the urban than in the rural areas and also that a very large number of rural scholars never get more than a mere smattering of the most elementary education; so that educational efficiency in rural areas is very much lower than the official returns of general education would indicate. I may appropriately refer here to a small brochure entitled "A Policy of Rural Education" by Mr. S. H. Fremantle[1], the Collector of Allahabad, which has quite recently been published and which is well worthy of perusal. He complains how both in urban and rural schools education is too literary and how primary schools are worked for the benefit of that small section which can afford a secondary education and not in the interests of the overwhelming majority of agriculturists, most of whom abandon their studies after a few months. I think Mr. Fremantle is right. It means that very few indeed of the agricultural population get any education at all, and that, as a class, it can be put down as almost illiterate. The authorities have not been ignorant of these facts, and it is not from want of trying to improve matters that things are at such a low ebb. Much has been done in recent years to improve our system of education, especially in its relation to agriculture and the subject may be said to have received an unwonted measure of attention. In 1901 an important Conference was held at Simla presided over by Lord Curzon which led to a complete overhauling of the existing educational machinery. A policy of reform was then started, the vitalizing influence of which is felt to this day. A department of education was created with a member of council in charge. Money grants were increased and they have still further increased, as a result of keen interest taken by the present Viceroy, Lord Hardinge, who has made education a special object of his attention. Thus the total expenditure which in 1901 was 4 crores, to-day is over 10 crores. The number of pupils in 1901 was 3¾ millions, to-day it is 7½ millions. Interest has been stimulated in every quarter and expansion is noticeable in every branch.

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[1] Fremantle, S. H., *A Policy of Rural Education.* W. Newman & Co., Calcutta.

Agricultural and rural education have had quite a fair share of attention, and the need which exists for connecting the teaching of the schools with our chief industry has been and still is fully recognized. I therefore do not complain of want of endeavour. But it cannot be said that these efforts have been crowned with the success one would have wished. But if we have to admit failure, whether complete or partial, we have gained considerably by the discussions which have resulted and by the light which has been thrown on the difficulties inherent in the problem.

The occasion when agricultural education first seriously engaged the attention of Government and the people was in 1904, when the policy for improving the agricultural industry was started by Lord Curzon. At first it was the intention to restrict efforts to improving the industry itself, but later, influenced no doubt by the examples of advanced schemes abroad, the Government elaborated a policy under which not only research and experiment, but agricultural education proper, formed an important and integral part. Large sums of money were devoted to the erection of agricultural colleges in nearly all the Provinces. Syllabuses were prepared by the Board of Agriculture and the Colleges were empowered to grant a diploma of Licentiate of Agriculture. At first, signs of success were not wanting. Candidates freely offered themselves for admission and there was found no difficulty in filling the colleges. However, as time rolled on, a decline in admissions became perceptible until the year 1913 when, in some colleges, the position became acute and the matter was brought up for consideration before the Board of Agriculture. The proceedings of the Board in that year indicate the general failure of the schemes drawn up in 1906 and 1908, and we find it expressed that the courses were found not to be suited to the class of students for which the colleges were intended, that the demand and utility for the course is obscured by its being made a road to a degree, that college graduates engaged on the subordinate staff of the Agricultural Department, with very few exceptions, failed to show any power to develop any original line, that intelligent inquisitiveness and power of independent thought was lacking, that the course engendered too much cram and too little power of application, and so forth. What was the root-cause of this failure would appear to be explained in one of the resolutions which stated "that the general standard embodied in the Matriculation or University Entrance Examination does not provide a sufficient basis to enable a student to take full advantage of the higher instruction obtainable in the existing agricultural colleges in India"[1] and the Board recommended that a general higher education is necessary in all students admitted to such a course. In other words, it would appear that the standard of general education in the country was too low to afford suitable material with which to man colleges of such an advanced type as those which had been set up by the Agricultural Department. In fact, the colleges as educational centres were ahead of the times—primary and secondary education was too backward. Consequently the Board suggested a compromise by lowering the standard of the college curriculum to meet existing conditions and expressed its approval of a two years' preliminary practical course, which had been prepared for the agricultural college at Coimbatore as an introduction to the more advanced course. Many of the colleges have since adopted this, with the result that admissions have considerably increased. While we may expect that the Department will benefit by an increase of recruits for filling its subordinate posts, it has yet to be seen how far the education of the cultivators will be influenced by the change. My own view is that these colleges as instruments for education will not accomplish very much, for the simple reason that they are ahead of the times and that there can be no real demand on the part of the youth of the country for an advanced agricultural course until considerable progress has been made in primary and secondary education and in the improvement of agricultural methods. Not until the industry is more highly developed and the standard of living has been raised, will there arise a demand for higher education amongst the agricultural classes.

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[1] *Proceedings of the Board of Agriculture in India*, 1913, p. 42. Government Printing, India, Calcutta.

The creation of agricultural colleges, however, is by no means the only effort that has been made to improve the education of our agricultural youth. Agricultural schools under the supervision of the Agricultural Department have been started in some provinces which were commended by the Board. They give considerable promise of success and, in my belief, deserve every encouragement. Also, there have been attempts in all provinces to set up a system of rural education by imparting instruction based upon the agricultural surroundings of the children, and endeavours have been made to use nature study as a means to that end. But so far the results, we must admit, have been of a microscopic character.

But there is a form of education which is not included in those I have mentioned and is unknown in India. It is a form of education which has been adopted in certain parts of America and which has of late attracted a considerable amount of attention. It is, in my humble opinion, applicable to the conditions existing in India, and offers opportunities in which officers of the Agricultural and Educational Departments could profitably combine to make the problem of education of the masses easier and more efficient. I will give a brief description.

In America general education is carried on chiefly by the Government by whom large sums of money are yearly allotted to the cause of education, but privately supported colleges are abundant and both these and Government schools are largely assisted by private benefactions, the most important of which are controlled by a private body known as the General Education Board.

Ten years ago great interest had arisen in the upraising of the Southern States whose industrial and educational conditions had fallen very much behind those of the Northern States. Conditions in the Southern States resemble in many particulars those which obtain in rural India. About 80 per cent. of the population is agricultural, depending for its livelihood almost entirely on the produce of the soil. There was great backwardness in both educational and industrial progress. Unfavourable economic conditions existed which were mainly the result of rural poverty. While the average annual earnings of agriculturists in the Northern States were more than 1,000 dollars, those in the Southern States were as low as 150 dollars. Under the auspices of the General Education Board an enquiry was set on foot to study the educational conditions in the Southern States and to devise the ways and means for improving them. The very practical way in which the enquiry was conducted is characteristic of the American people. Surveys were planned State by State, conferences were held, monographs were prepared, dealing with the various points on the organization of education. The conclusions which resulted from this enquiry are peculiar. To quote from the Report, it "convinced the Board that no fund, however large, could, by direct gifts, contribute a system of public schools; that even if it were possible to develop a system of public schools by private gifts, it would be a positive disservice. .... The public school must represent community ideals, community initiative, and community support, even to the point of sacrifice."[1] The Board therefore resolved that assistance should be given not by foisting upon the Southern States a programme of education from outside, but by aiding them and co-operating with them in educating themselves. When, however, it proceeded to apply these principles it was faced with the following initial difficulties. They found the people had not enough money, "that adequate development could not take place until the available resources of the people were greatly enlarged. School systems could not be given to them, and they were not prosperous enough to support them." "Salaries were too low to support a teaching profession...............Competent professional training could not exist; satisfactory equipment could not be provided."[2] These conditions were primarily the result of rural poverty. The great bulk of the people was not earning enough to provide good schools and the prime need was money. The Board therefore came to the conclusion that it could render no substantial educational service until the farmers could provide themselves with larger incomes, and consequently they resolved that it was necessary first to improve the agriculture of the Southern States. Now mark what followed. The Board was first advised to address itself to the rising generation and to support the teaching of agriculture in the common schools. But after thoughtful consideration this plan was rejected. They found that in the absence of trained teachers, the effort was impracticable; moreover, there were no funds with which to pay such teachers, and the instruction itself would not materially contribute to its own support. Finally, it was impossible to force intelligent agricultural instruction upon schools whose patrons were not themselves alive to the deficiencies of their own agricultural methods. Until the public was convinced of the feasibility of superior and more productive methods the public schools could not be reconstructed; once the public was convinced and, by reason thereof, better able to stand the increased cost, the schools would naturally and inevitably re-adjust themselves.

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[1] *General Education Board. An Account of its Activities*, 1902—1914. 61 Broadway, New York.

[2] *Ibid.*

"It was therefore deliberately decided to undertake the agricultural education not of the future farmer, but of the present farmer, on the theory that, if he could be substantially helped, he would gladly support better schools in more and more liberal fashion."[1] The Board, therefore, set about an extensive enquiry as to the best means of conveying to the average working farmer of the South, in his manhood, the most efficient known methods of intelligent farming. As a result of this enquiry a movement known as the Co-operative Farm Demonstration was set up. A year was spent in discovering the most effective methods of teaching improved agricultural methods to adult farmers. Dr. Seaman Knapp of the United States Department of Agriculture was engaged to show farmers how to improve their agricultural methods and raise the standard of their industry. It was not long before successful results were obtained. Under improved treatment it may be roughly stated that the crop yields were doubled. Thus in 1909 the average yield in pounds of seed cotton was 503·6 per acre: on demonstration farms the average was 906·1 pounds; in 1910 the figures were 512·1 and 858·9 respectively; in 1911, 624·6 and 1081·8; and in 1912, 579·6 and 1054·8.

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[1] *General Education Board. An Account of its Activities*, 1902—1914.

In the growing of corn similar results were obtained. In 1909 the ordinary average yield was 16·7 bushels per acre, while on the demonstration farms it was 31·7 bushels per acre. In 1910, 19·3 and 35·3, in 1911, 15·8 and 33·2, and in 1912, 19·6 and 35·4. It is further stated that the poorer the season, the more clearly did the demonstration methods prove their superiority. The work was also studied from the standpoint of the farmer's financial profit. "In Alabama, for example, in 1912, the average yield of lint cotton was 173 pounds per acre; but demonstration acres averaged 428·3 pounds. Demonstration methods, therefore, netted the farmer 255·3 pounds per acre. At the average price of 65 dollars a bale for lint and seed, the farmer made an extra 33 dollars per acre; as there were 8,221 acres under cultivation on the demonstration methods, the total gain was 271,000 dollars. In the same year 7,402 acres were under cultivation in demonstration corn. Demonstration acres averaged 26·9 bushels more per acre than the general average for the State. The demonstration farmers of the State pocketed 139,379·66 in consequence."[1] This was of course in one State alone. These methods have not been restricted to cotton and corn, but have been applied to a very large number of crops and the propaganda is not limited to cultural methods, but is applied equally to the improvement in farm equipment, more comfortable houses, better barns, stronger teams, better implements, and cleaner and healthier surroundings. Hence it is claimed that the beneficent results of this work are not limited to financial profit and cannot entirely be measured by money. Characteristic examples of the relief which the new system brought are cited, but one example will suffice. In Mississippi 5 years ago the value of a certain farmer's produce was one dollar per acre and he was 800 dollars in debt. In 1909 his entire farm was worked under the Government method. He averaged 1,100 lb. of cotton against his neighbour's 300 to 400 lb. He made besides 500 bushels of corn and from one special demonstration acre realized 152 barrels of high class seed which he sold for 300 dollars. His debts are now paid and he has cash in the bank. So much for the education of the adult farmer. We now come to the effect this movement has had on the education of youth. We are told that the initiation of demonstration work and the application of the principle of co-operation has resulted in the disappearance of the disorganization characteristic of rural life. Colleges of agriculture, farmers' institutes, agricultural high schools, "Boys' Corn Clubs," "Girls' Canning and Poultry Clubs," and the like have been brought into existence where practically none of these things existed before, and that the social and educational awakening of the rural South is recognized as being a bye-product of the demonstration movement. Statistics show that the provision for schools has steadily increased. Thus the expenditure for public, elementary, and secondary schools in North Carolina which was 1,091,226 dollars in 1901, is 4,300,000 in 1913. In South Carolina the expenditure which was 961,897 dollars in 1901 is 2,609,766 in 1913, Arkansas 1,369,809 and 4,279,478, and so forth. These instances give but meagre examples of the important results achieved by the demonstration movement. For greater detail I must refer you to the Report[1] itself.

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[1] *Ibid.*

I think you will agree with me that the educational policy I have described is novel and peculiar. When I say novel, I do not mean that demonstration work has not been used before among farmers and cultivators. We all know that it has, but it is novel in the sense, that never before, so far as I am aware, has demonstration been used in any country as a force and weapon for education so as to make it a condition precedent to the education of youth. It is a new experiment but a new experiment of a remarkable kind. The results indicate that it is no use to try and educate youth if you do not first secure the welfare of the community to which it belongs and that therefore the development of resources should precede education in order of time. What the American General Board of Education says to the farmer in the Southern States is—You are too poor to supply your sons with education; we could assist you, but we do not consider it proper to do so, unless you yourselves contribute. As you cannot do this, we will assist you to increase your earnings so that you will be in a position to provide yourself with schools. When you have done this we will assist you further. We consider that it would be wrong for us to directly educate the rising generation, if you are not able to participate; in fact, we believe that it would be a positive disservice for us to do so. Your schools should be started by yourselves, they should represent community ideals, community initiative, and community support even to the point of sacrifice.

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[1] *Ibid.*

We have seen how the experiment has succeeded. Might we not with advantage apply the same principles to India? Might we not invite the co-operation of the Agricultural Department in a general scheme and policy of education? Is there any likelihood of success without this? Can we hope to give the youth of this country an adequate educational service unless we go to the root of things, like the Americans have done, and enlist and increase the activities of the Agricultural Department in enlarging the resources of the cultivator and thus build our educational system on the increased prosperity of the agricultural classes? These are the questions I desire to offer for consideration. India is in no better position than the Southern States were ten years ago. Indeed I think we may safely assert it is in a far worse position. The average earnings of individuals in the Southern States at that time were 150 dollars. In India, according to some authorities, under the most optimistic calculations, they are as low as Rs. 30 per head. You must agree this gives little or no scope for self-help. It therefore seems to me plain that under present conditions we cannot expect the country to supply itself with the means for an advanced system of education. Nor can Government be expected to do so, for Government's resources are limited and depend upon taxation, and that in turn depends upon the ability of the people to be taxed. All Government can do is merely to touch the fringe of the problem and supply a modicum of education; it cannot afford to do more. Mr. Fremantle very well describes the situation when he says: "We should surely pause to consider whether the time is ripe for the introduction of a system of general primary education into rural areas. It is a question whether we are not beginning at the wrong end and whether primary education can make any real advance before there is a substantial improvement in economic conditions."[1] These are words which the devotees at the shrine of the policy of free education for the masses might with advantage ponder.

The question then is whether we can, in any way, make the principles which have been so successfully applied in America, applicable to India. My belief is that we can. We have practically the same conditions here as obtained in the Southern States ten years ago. If anything, as I have shown, they are a good deal worse. But this is no argument against their adoption. Rather the reverse, for the lower the degree of prosperity, the greater is the need for increasing it. Already in the Provinces a great deal has been done by the Agricultural Department in the way of demonstration of the character described and utilized by the American Board of Education. But it does not go far enough. It, however, forms a nucleus on which to expand and might well be used as a beginning. The work is on the right lines. But we require to do more. We want more men, more money, wider organization; but, above all, we require the recognition amongst all classes that in this work lies the germ of future progress. This is a point which is not generally recognized, or, if so, it is certainly not acted upon. While the money spent to-day on education is over 10 crores of rupees, that on agricultural development is only 50 lakhs. That shows that we have not yet got to view these two important problems in their right perspective, and do not fully realize the important relation which agriculture bears to education. Many think that the development of agriculture depends on education, and we gave effect to that view when we started our agricultural colleges. But would it not seem that the truth lies in the opposite direction, and that in a backward country like India the advance of education is really dependent on the development of agriculture, and that the best form of education you can give to the rural classes under existing circumstances is demonstration in improved agricultural methods ? It was found to be so in the Southern States of America and we have no reason to suppose it is otherwise in India. To carry out the idea it is not necessary to bring our present educational policy to an end. I would not propose anything so revolutionary. Government must, as I have already explained, supply a modicum of literary teaching and this must continue, but it would be an immense improvement if the Agricultural Department were called in to co-operate and demonstration were given a large share in the general scheme of education.

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[1] "A Policy of Rural Education," W. Newman & Co., Calcutta.

We could not be expected at first to progress with the same degree of rapidity as in America, because we have to do a large amount of research and experiment before we can demonstrate improved methods on a large scale. In America the advanced stage in the agricultural development of the Northern States supplied ready at hand the stock-in-trade required for at once setting in motion the demonstration movement in the backward Southern States. We are not so forward. Still we have achieved enough with our small band of workers to show that the same kind of work can be done out here and that all we require is expansion. Given the means for this (and who will say it would be a bad investment ?) and a recognition of demonstration as an integral part of a general scheme of education, and I feel sure we shall, by such a policy, lay the best and securest foundations for the advancement of education as well as of the prosperity of the people.

THE APPLICATION OF BOTANICAL SCIENCE TO AGRICULTURE.

BY

ALBERT HOWARD, C.I.E., M.A.,

Imperial Economic Botanist, Pusa.

I. INTRODUCTION.

A study of the literature dealing with agriculture indicates that there is some confusion of ideas as to the precise relation which exists between the science of botany on the one hand and the practice of agriculture on the other. In the present paper, an attempt has been made to define the bearing of the scientific aspect of the vegetable kingdom on the economic development of crop-production and to show how a knowledge of this science can best be applied to agricultural problems. A new term has recently grown up—Agricultural Botany—and text-books have appeared thereon as if a new branch of the science had been developed. Agricultural botany is supposed to be easier than ordinary botany and to be more adapted to the needs of the students in agricultural colleges. It is often assumed that in such colleges only a rudimentary knowledge of botany is required and that the examples used in teaching must of necessity be taken from cultivated crops. It is even thought that students trained in this manner will develop into investigators and that advances in agriculture can be achieved by such agency. I venture to assert that nothing could be further from the truth and that, in this direction, there is no royal road to success and that the final result of such endeavours can only be disappointment. For any real advance to be made in crop-production, a thorough scientific knowledge of botany in all its branches is one of the first conditions of progress. This will be clear if the real problems to be solved are considered in all their bearings.

The attempt to improve cultivated crops by scientific methods is a recent development and can be traced to two main causes—(1) the gradual recognition of the fact that in agriculture the plant is the centre of the subject; and (2) the rapid rise of the study of genetics which followed the re-discovery of Mendel's results in inheritance.

Starting from Liebig's application of chemistry to agriculture, an enormous amount of chemical investigation, relating to the composition of the soil and of the plant, took place and for a time great hopes were entertained that in this direction important progress could be made. These expectations were not fulfilled, and gradually the chemists broadened the basis of their investigations and took into consideration the physical character of the soil, its geological origin, and the natural vegetation found growing therein. In this manner, modern soil-surveys have arisen in which the importance of the plant as a living organism has been slowly recognized. Recently, the development of genetics has drawn still more attention to the plant and this recognition is reflected in the present constitution of the staffs of up-to-date Experiment Stations. Side by side with these changes, the studies of disease in plants have to some extent receded in importance as is well seen if the present staff of the Bureau of Plant Industry of the United States Department of Agriculture is compared with that of twenty years ago when this Bureau was almost entirely composed of mycologists and when the advice given by the botanists was largely confined to the treatment of plant diseases.

The importance of the plant in crop-production may be said to be generally recognized at the present time. A large number of botanists are being employed at Experiment Stations and the public have often been led to expect that a revolution is about to take place, particularly through the application of what is popularly known as Mendelism. A critical examination of the literature discloses some signs that these extravagant hopes are not likely to be fulfilled, not that these hopes are impossible but rather because the problems have not always been taken up on a sufficiently broad basis and attacked simultaneously from several standpoints.

II. The Development of Botany.

A brief review of the manner in which botanical science has developed will help to make clear the great difficulties which must first be surmounted before any results of real practical value can be obtained.

As is well known, the origins of modern botany are to be traced to the old herbals of the sixteenth and seventeenth centuries and to a period when plants were studied chiefly from the medicinal point of view. It was then essentially a field study out of which the modern ideas on classification slowly emerged. The development of the microscope, while leading to immediate and far-reaching advances, necessarily focussed the attention of investigators on the anatomy of plant organs and on the study of the various structures met with in these researches. Similar particularist tendencies arose in the growth of systematic botany and undue attention was often paid to the study of the floras of various regions from the point of view of herbarium specimens alone. The growth of physiology was too slow to remove entirely the evils of a somewhat formal and one-sided development which was reflected both in teaching and research. Physiological investigations are notoriously difficult and the greatest patience and skill are necessary in advancing our knowledge of the various functions in the plant. The manner in which botanical science has developed and the necessity of dealing with large classes of students in Universities, have necessitated a somewhat formal presentation of the subject in separate sections such as morphology, anatomy, physiology, and systematy. Much of this sub-division is inevitable but it renders difficult a proper conception of the plant as a living whole, as a complex factory which takes in, by way of the roots, various mineral salts in solution in water and, by the leaves, oxygen and carbon dioxide from the air, working all these raw materials up into complex food substances by means of energy focussed from the sun through the medium of the chlorophyl corpuscles. The plant is continually manufacturing new food, developing new organs, and completing its life cycle under constantly varying conditions as regards moisture, food materials, temperature, humidity, and illumination. The vegetable kingdom is like a multitude of exceedingly complicated and competing hostile factories which have to carry on their activities under all sorts of rapidly varying circumstances. Any failure to meet the changes in the working conditions, caused by weather or by shortage of water and mineral salts in the soil, may mean the stoppage of the factory and the extinction of the organism. In this competition, all the combatants are armed to the teeth and possess all kinds of devices to assist in the struggle for existence. If any space in the sun is yielded by one of the competing factories, it is instantly seized by the rest. The limitation of armaments is an impossible conception in the vegetable kingdom. It is no easy task for the student to appreciate fully the many-sided aspects of the living plant and to master the manifold details of a science, still to a large extent in the descriptive phase of development, particularly when that subject is presented to him in parts often very loosely bound together. The investigator too is hampered in this direction by the necessity of specialization and of narrowing down the conditions of a problem so that the ordinary clear cut methods of academic research can be applied. It requires a conscious mental effort on the part of a botanist to regard the vegetable kingdom as a whole and not to think of it only in terms of systematy, physiology, or of anatomy. Training in research in any particular branch does not necessarily widen the general outlook, although it is of the greatest use in other ways.

The more recent developments in botanical science are fortunately all tending to a study of the plant as a living whole. Both the scientific study in the field of plant associations (ecology) and the systematic examination of the various generations of plants raised from parents which breed true (genetics) are doing much to mitigate the evils which follow from undue devotion to purely laboratory work. Ecology and genetics are taking the botanist into the field and will, in all probability, materially influence the future development of the science. This will be all to the good and should do much both to raise the standard of and emphasize the importance of field work and also develop the natural history side of botany. The botany of the future is likely to combine all that is valuable in laboratory work with modern ideas on ecology, classification, and genetics.

III. THE RELATION OF BOTANY TO AGRICULTURE.

We have seen that from the nature of the subject and arising out of their training, most botanists experience difficulty in realizing fully the plant as a living whole in which one part reacts on another. A wide scientific outlook on the many aspects of plant life is nevertheless the first condition in applying botanical science to practical problems. It is, however, by no means the only one. The next step for the botanist is to study his crop in the field and to learn to appreciate the agricultural aspects of crop-production. In other words, he must study the art of agriculture as applied to his particular problem. Too much stress cannot be laid on this. The investigator must himself be able to grow his crop to perfection and it is not too much to say that no real progress can be made without this. The ordinary agricultural processes applied to any crop bear a direct relationship to the physiological necessities of the plant and have been evolved from centuries of traditional experience. Thus in the growth of *rahar* (*Cajanus indicus*) in many parts of India, it is the custom to dig the land at the end of the monsoon as by this means the yield is increased. The physiological basis of this operation is the necessity for the provision of abundant air for the root-nodules in an alluvial soil consolidated by heavy monsoon rainfall. Indeed the agricultural processes necessary to grow a crop to perfection in India are nothing more than lessons in physiology learnt by experience through a long period of time. In all investigations on crops, a first-hand knowledge of practice is necessary and nowhere is it so important as in plant-breeding work where practice is quite as valuable as an acquaintance with the methods and results of genetics. The greatest devotion to the study of inheritance, using for this purpose material indifferently grown, is largely labour lost as many characters are masked unless the plants are really thriving and well-developed. For instance in wheat, the red colour of the chaff never develops in badly grown plants thereby causing great confusion in systematic and breeding work on this crop. In tobacco, the various leaf characters are almost entirely masked by bad cultivation and their inheritance can only be studied if the crop is grown to perfection.

The investigator, after having learnt how to grow plants and having mastered agriculture as an art, must proceed to study his crops in the field. It is not sufficient to plant the seed and wait till flowering time and harvest come round for the results. Daily contemplation of the growing crop and observation of the plant through its whole life-history will suggest many new ideas and do much to train the observer, and develop the power of accurate deduction and real agricultural insight. In variety trials and field experiments, the necessity of constant observation of the growing crop is seldom recognized. An even plot of land is selected, the crop is sown and the harvest weighed. Should the season be abnormal, this circumstance is often recorded. It is somewhat dimly perceived that the quantitative results of any year partake of the nature of an accident, but it is thought that a repetition of the experiment for, say, fifty to one hundred years and the striking of an average result will remove most of the effects of disturbing factors. It is true that this expensive and time-consuming procedure will give the mean result under the conditions of the experiment provided all due care is taken in carrying out the work. On the other hand, a constant observation of the growing crop by a fully qualified observer will lead to the deduction of the factors on which yield depends far more rapidly and accurately than can be done by such a mechanical method. Constant observation of the growing crop is therefore of the first importance. In course of time, the observer learns how to read his practice in the plant and, at the same time, he develops from hardly won experience a sympathy and understanding of the cultivator and of the grower's point of view. The raising of crops is a most useful discipline for a young investigator fresh from the university, and it also serves rapidly to remove any intellectual arrogance he may possess in his attitude towards the farmer or cultivator. First-hand practical experience will thus assist towards producing a proper relationship between the scientist on the one hand, and the practical man on the other. This apprenticeship will, at the same time, serve to eliminate at the outset men who lack a practical turn of mind. The agricultural public judges largely by eye, and is not trained in the rapid digestion and understanding of printed reports. Well grown crops at an experiment station are much more telling than printed bulletins however well-illustrated these may be. In dealing with the would-be improver, the attitude of the agriculturist is often one of amused scepticism as, among themselves, deeds always count much more than words and the benefits of education are not always regarded with enthusiasm. "Show me thy cultivation and I will tell thee what thou art" is merely putting into words the view of the countryside towards a new arrival in its midst. The agricultural investigator must also pass through this ordeal with credit to himself before he can hope to establish his position and hold his own with the tillers of the soil.

Science and practice must be combined in the investigator who must himself strike a correct balance between the two. The ideal point of view of the improver is to recognize agriculture as an art which can best be developed by that instrument called science. Once this is fully realized and acted upon, the place of the experiment station in agriculture will be understood as a matter of course and the qualifications needed by the workers will be self-evident. There will be little or no progress if practical agriculturists are associated with pure scientists in economic investigations. This has often been tried and has never yielded results of any importance. The reason why such co-operation fails is that without an appreciation of practice, the scientist himself never gets to the real heart of the problem. The history of the indigo investigations in India is a very good case in point. During the last 20 years, a number of scientists have been employed in an endeavour to improve the production of natural indigo. Over £50,000 have been expended on this work between 1898 and 1913 but no results have been obtained, largely because the scientists preferred to engage European assistants on indigo estates to grow their experimental crops rather than to cultivate them themselves. The result was that the real problems were not discovered, a large amount of ineffective work was done and valuable time was lost during which the natural indigo industry declined and the synthetic product rapidly established itself in the markets of the world. The solution of the indigo problem has recently been disclosed by a study of the plant in the field. It is not too much to say that if a properly qualified botanist with a knowledge of agriculture had attacked the indigo problem twenty years ago, the history of this industry would have been very different.

There remains for consideration the commercial aspect of investigations on crops and the necessity, on the part of the worker, of keeping in close touch with the requirements of the trade. Particularly is this important in the case of materials used in textile industries like cotton where any marked alteration in the raw product might easily involve extensive changes in machinery. In the case of cereals like wheat, it is necessary in improving the variety to follow closely the needs of the manufacturer and to ensure that any new types introduced into general cultivation can be milled to advantage. If grain quality, of increased commercial value, can be secured as well as higher yielding power, the combination is all to the good. The investigator must therefore study trade requirements and be able to make use of the experience and knowledge of the men who handle and use produce on the large scale. The successful merchant often possesses information which is of the greatest value to the botanist and which helps the investigator to perceive the manner in which an improvement can most effectivel be made. Just as the success of a commercial man depends on his ability to determine the direction in which he can improve his method or his product above those of his competitors, so the investigator must possess a similar practical instinct. He must be able rapidly and unerringly to decide in which direction the maximum improvement is possible.

That a combination of science, practice, and business ability in the same individual is essential in all agricultural investigations dealing with the plant will be evident if the kind of problem awaiting solution is considered in detail. Many of these questions fall into the following three classes :—

(1) *Improvements in the efficiency of the plant.* If we regard the plant as a factory and a crop as a number of factories, the aim of the grower is to produce the largest possible output of some plant product—seed, leaves, roots, stems, or flowers. In stimulating a crop to produce the maximum in any one direction, the factory as a whole must be considered and the machinery must not be thrown out of gear. The physiological aspects of growth must be clearly kept in mind as well as the conditions under which the translocation of reserve foodstuffs takes place. We can, for example, often increase the yield of leaf in a crop like tobacco by suitable manurial treatment such as a copious supply of nitrogenous food material, but the resulting loss in quality is so great that the extra weight would result in financial loss. We should merely produce in this way badly ripened leaves in which the proper development of colour and flavour during curing would be impossible. Any attempt to increase the output of a crop can only be successful if the physiology of the plant is considered together with the economic aspects of production. Such problems have to be solved within the working conditions of the plant factory and also within the general economic limits imposed by labour and capital. In such matters, the investigator might easily go astray unless he keeps the laws of plant physiology in view and unless he is fortified by a knowledge of practice and an appreciation of the general working conditions.

(2) *The treatment of disease.* The inadequacy of much of the experiment station work on the diseases of plants, in which fungi and insects are concerned, has recently been referred to by Professor Bateson[1] in one of the sectional addresses to the British Association :—

" Nowhere is the need for wide views of our problems more evident than in the study of plant diseases. Hitherto, this side of agriculture and of horticulture, though full of possibilities for the introduction of scientific method, has been examined only in the crudest and most empirical fashion. To name the disease, to burn the affected plants, and to ply the crop with all the sprays and washes in succession ought not to be regarded as the utmost that science can attempt. There is at the present time hardly any comprehensive study of the morbid physiology of plants comparable with that which has been so greatly developed in application to animals. The nature of the resistance to disease, characteristic of so many varieties, and the methods by which it may be ensured, offer a most attractive field for research, but it is one in which the advance must be made by the development of pure science, and those who engage in it must be prepared for a long period of labour without ostensible practical results."

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[1] *Report of the British Association for the Advancement of Science*, 1911, p. 590.

A diseased condition in a plant usually arises from some profound interference with the normal physiological processes after which a pathological phase gradually develops. The protoplasm and cell-sap become charged with waste products and a parasitic fungus is then able to destroy the tissues. An invasion of fungus mycelium is usually impossible when the plant is in health as protoplasm is strong enough to resist any attack and the cell-sap is not in a suitable condition to nourish the fungus. The parasitic fungus and the destructive insect are often consequences rather than the real causes of disease and are merely the last phase in the death of a moribund organism. The Java indigo crop in Bihar[1] has recently furnished an interesting example of the necessity of a wide outlook in the investigation and treatment of plant diseases. A diseased condition, known locally as *wilt*, began to make its appearance some years ago after which it rapidly spread all over Bihar. About the middle of the monsoon, the plants were observed to drop a good deal of leaf and the remaining foliage was seen to change in appearance, becoming a greyish, slaty colour. Growth finally ceased after which the plants slowly died during October and November. Not only was the yield of dye seriously reduced, but the affected plants yielded hardly any seed. For this reason, the area under Java indigo in Bihar rapidly fell from 70,000 bighas in 1910 to about 15,000 bighas in 1913. Investigation of this disease yielded no results, and it was found that none of the insects, fungi, or bacteria associated with the affected plants were responsible for the trouble. For the moment, science seemed entirely at a loss in suggesting any practicable means by which the final extinction of the indigo industry could be prevented. In reality, however, the position was in no respect hopeless. Examination of the affected crop showed that the leaf-fall and wilt were connected with the destruction of the active root-system of the plant, including the nodules, as a result of interference with the air-supply of the roots brought about by a constantly wet condition of the soil during the long monsoon phase. The wilt disease was found to be the last stage in starvation caused by the cutting off of the supply of one of the essential raw materials—air—needed by the roots and root-nodules. Evidently the line of attack lay in the direction of increasing the air-supply in the soil and in assisting the plant to withstand the constantly moist soil conditions which set in during the monsoon. This was done by improving the methods of cultivation during the hot weather and by the provision of surface drainage, by which each field was cut off from the run-off of other areas by a suitable arrangement of trenches. The problem of the seed supply was solved by August sowings on high-lying, well-drained fields. In this manner, the plants were able to withstand the wet soil conditions of the second half of the monsoon without injury and to yield fine crops of excellent seed. The yield of dye was materially increased by thorough cultivation in the hot weather combined with surface drainage. The history of the indigo disease in Bihar furnishes a very good example of the necessity of a broad outlook in dealing with diseases of crops and for regarding the plant as a complex factory in which injury to any one part often upsets the whole machinery.

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[1] Howard and Howard, *The Improvement of Indigo in Bihar*, Bulletins 51 and 54, Agricultural Research Institute, Pusa.

(3) *The creation of improved varieties.* In the development of an industry like the manufacture of cotton cloth from the raw material, there is, as is well known, a constant substitution of the

existing machinery by improved types and the scrapping of old plant is continually taking place. In like manner in agricultural development, the substitution of existing varieties by improved forms is constantly being carried out, and in many European crops the varieties grown a hundred years ago have almost disappeared. In crop-production, as in cotton factories, the size of the scrap-heap is one of the indications of the rate of progress. The creator of new varieties of plants must obviously be even better fitted for his task than the engineer who improves spinning and weaving machinery. In a cotton factory, improvement can be made in detail whereas, in the plant, the whole factory must be replaced by a new one and the variety changed. To develop an improved variety and to utilize botanical science to the best advantage, it is clear that the problem to be attacked must first be understood in all its bearings. We require to know by experience the general agricultural conditions of the tract in which the improved variety is to be grown, the kinds at present cultivated, the directions in which improvements are possible, and where the greatest economic advantage can be obtained. In other words, the problem must be simultaneously considered both from the standpoint of the cultivator and from the point of view of the trade. An understanding of the needs of the crop and a knowledge of systematy and genetics must be combined with the insight of the inventor. In such work, no possible scientific method can succeed without the intuition of the breeder. Any attempt to measure or record the characters of large numbers of plants and to obtain the final selections by a scientific system of marks is hopeless, as the investigator would be speedily swamped by the volume of his material. The insight of the breeder is necessary for the work and the judgment, which comes by practice, in the rapid summing up of essentials by eye is far more useful than the most carefully compiled records or any system of score cards. The successful plant breeder is to a large extent born and not made as is proved by the fact that without the aid of science great advances have been made in the breeding of stock, cereals, and in various branches of horticulture. Science helps the born breeder by providing him with new and better instruments and, by bringing knowledge to bear from many sides, it accelerates the output and lightens the work in a multitude of ways.

In the limits of this paper, an attempt has been made to indicate the class of problems in plant-production which await solution if progress in agriculture is to be obtained by the aid of botanical science. These problems are not simple, and often cannot be solved by the ordinary methods of academic research. Many of them can, however, be dealt with successfully if attacked simultaneously from several standpoints provided always that the investigators themselves are fully qualified for the work. As far as crops are concerned, progress can best be made by botanists, well grounded in pure science, who, at the same time, possess sufficient aptitude to master agriculture as an art and who also have the type of mind to be found in the successful inventor. In this direction, the field of work in the Empire is almost unlimited and the great universities, by helping to train the investigators of the coming generation, have a truly Imperial task to perform. Failure on the part of individuals will occur in the future as in the past, but one great cause of want of success will be removed if the all-importance of agriculture as an art in the equipment of the next generation of experiment station workers is recognized by all concerned. The State can do much in these matters by a practical recognition of the principle that the labourer is worthy of his hire and that the man, who makes two blades of grass grow where one grew before, deserves well of his country, and must be promptly and adequately remunerated.

IMPORTANCE OF SOIL-AERATION IN FORESTRY

BY

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Forest officers have long realized the importance of soil-aeration in Forestry in so far as this is connoted by such general expressions as "the physical condition of the soil," "water-logging," and so forth. The aspect of this question dealt with in the present paper, however, is one which has not yet attracted the attention it deserves, *viz.*, the damage that may be done to the seedlings of our forest trees by insufficient soil-aeration when the physical condition of the soil is apparently suitable for growth and when the soil, although moist, is far from being saturated with water. The results noted in this paper refer, it is true, to a single species only, *viz.*, the *sal* tree, *Shorea robusta*, but it is believed that they will be found to apply to a number of other species.

The seedling reproduction of *sal* in our Indian forests is by no means satisfactory. In many forests where conditions seem favourable no seedlings exist, and in others the seedlings die back for several years. Plate I, fig. 1 shows examples of *sal* seedlings which have died back for several years and which are typical of the majority of those found in the protected forests of Northern India. Note the thickened rootstocks and comparatively feeble shoot development. This dying back is usually considered to be due to drought. The whole plant here dies annually with the exception of the stout portion just below the ground level which persists and gradually increases in size and length until finally a persistent aerial shoot is also developed. This delay in the establishment of seedlings interferes with the economic management of our forests and entails a financial sacrifice in the loss of several years' increment. Drought, however, obviously cannot explain why seedlings frequently die wholesale during the rains nor why the dying-back is frequently more marked in the moist soil of the shady forest than in the drier soil in the open.

The following results dealing with the causes of the death and dying-back of *sal* seedlings have now been established by work recently carried out at Dehra Dun :—

(1) Seedlings grown under favourable conditions of soil and moisture in the Dehra garden do not, as a rule, die back. A few weakly individuals do die back, but the majority produce vigorous shoots which persist from the first and attain an average height of 13″ in one year and 26″ in two years.

Plate I, fig. 2 shows such seedlings one year old and also some weakly plants of the same age which have died back. These vigorous garden plants indicated the development which was possible under the local climatic conditions and the chief object of the present work was to attain or approach this ideal in the local forests.

(2) An experiment carried out in the Dehra garden, in 1913, showed that, if rain water was allowed to accumulate in non-porous pots, in which the basal drainage holes were tightly corked, and which were filled with the local *sal*-forest soil, the latter was soon rendered entirely unsuitable for the growth of *sal* seedlings, although it was by no means saturated with water. It was found that, under these conditions, 100 per cent. of *sal* seedlings were either killed or had their roots extensively rotted when the water-free air-space in contact with their roots was maintained at 450 c. ins. per c. ft. of soil, or less, for a period of 6 weeks, while seedlings in the same soil, in similar pots, but which were uncorked, remained healthy. This experiment was repeated in 1915 with practically the same results.

Plate II shows the appearance of the seedlings in these pots in September 1915. Note the healthy plants

PLATE I.

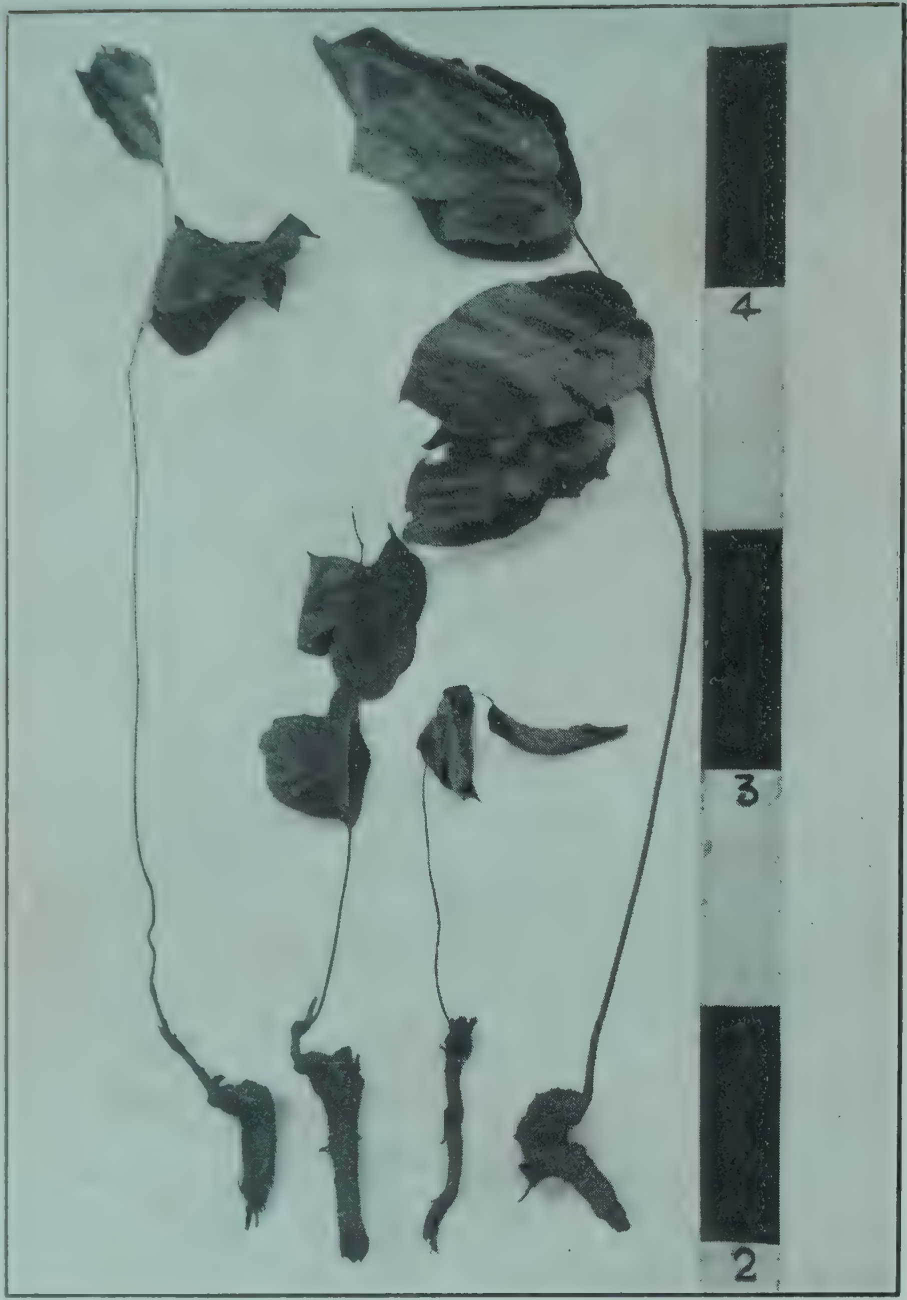


Fig. 1.

Sal seedlings typical of those found in the protected Dehra Dun forests. These have greatly thickened rootstocks and have died back for several years. The measuring staff appearing in this and the subsequent figures shows lengths of 6 inches, alternately black and white.

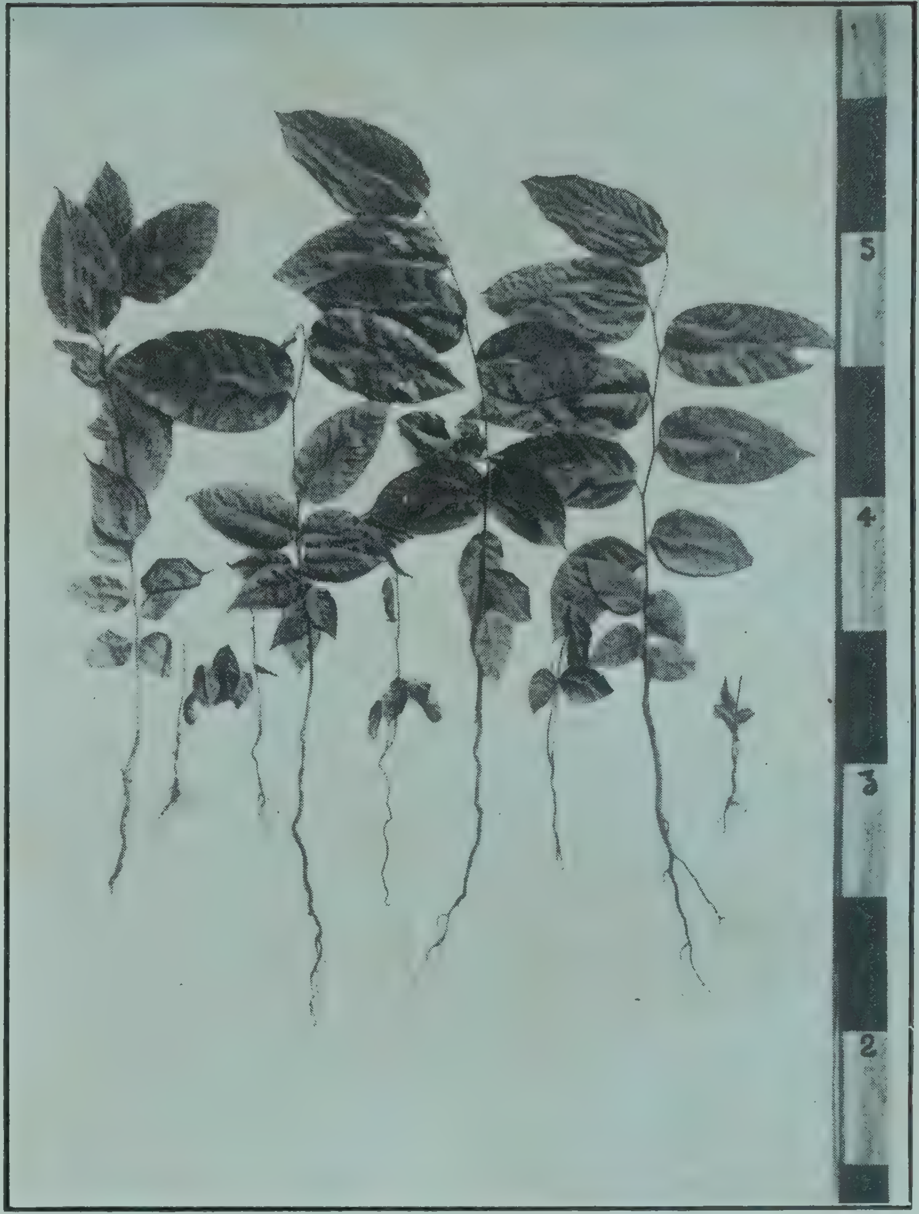
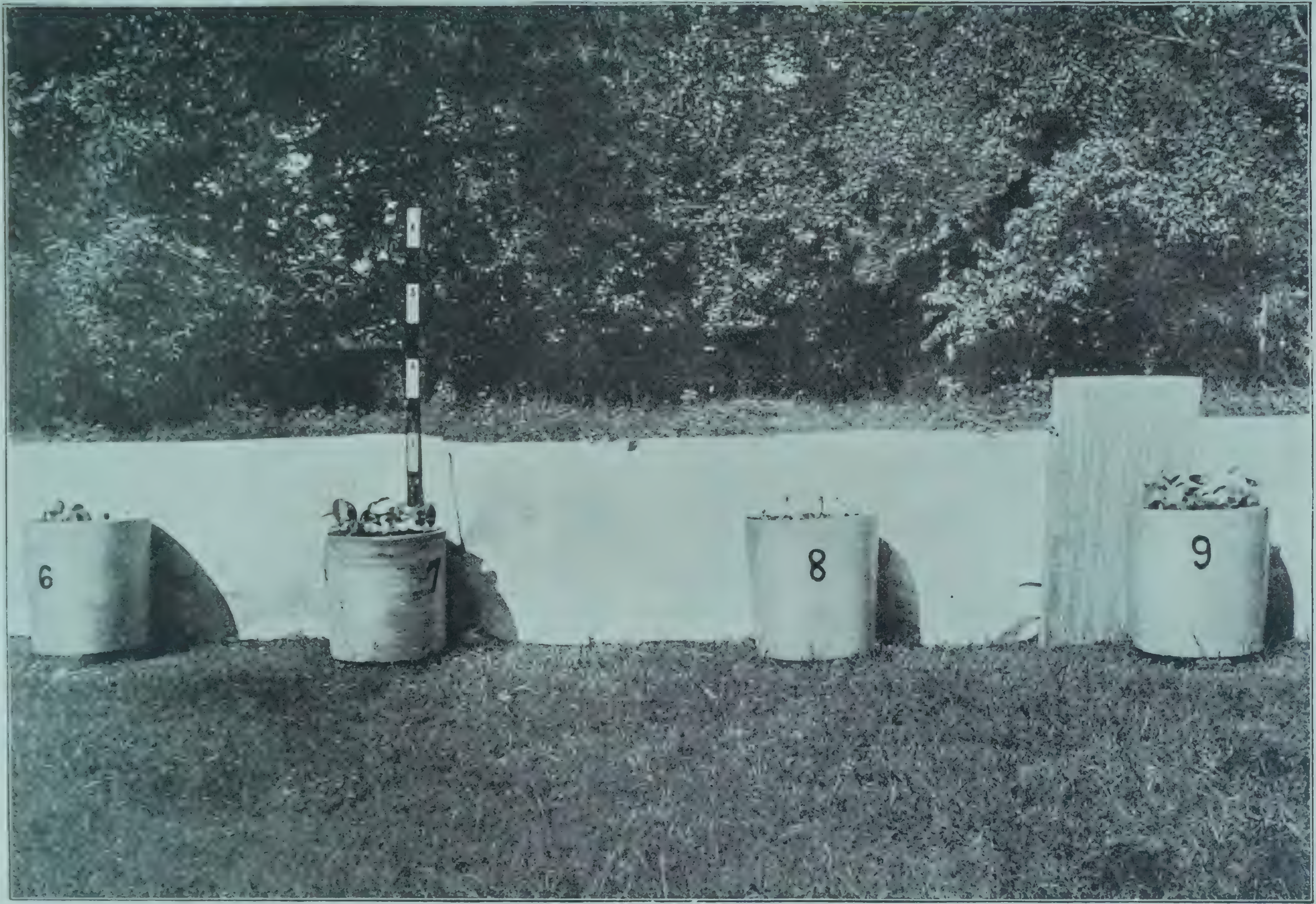


Fig. 2.

Sal seedlings, 1 year-old, grown under favourable conditions of soil and moisture in Dehra Dun Experimental Garden. The five small plants have died back. The majority of the plants, however, do not die back under these conditions and the four large specimens are typical of these. Such vigorous plants attain an average height of 13. 6 inches, in 1 year and 26 inches, in 2 years. This may be regarded as the ideal seedling development possible in the locality.

PLATE II.



Photograph taken 20th September 1915, showing *Sal* seedlings growing in *Sal* forest loam. Note the healthy growth in the uncorked pots 7 and 9, as compared with that in pots 6 and 8 which were corked on 30th July 1915.

in the uncorked pots 7 and 9 as compared with those in the corked pots 6 and 8.

This strongly injurious effect on *sal* seedlings of a constantly moist condition in loam was also obtained in an earlier experiment in which good basal drainage was provided, but in which the soil was kept constantly moist by merely diminishing the evaporation from the surface.

(3) Sowings in 1912-13 in sample plots in the shade of the local *sal* forests and on similar soil in the open outside the forests, respectively, resulted at the end of the first rains in 7 per cent. and 37 per cent., respectively, of healthy plants, calculated on the number of seeds sown. Similar sowings in the following year resulted in 17 per cent. and 86 per cent., respectively, of healthy plants. In these experiments the death of the large number of seedlings in the shade was preceded by more or less extensive rotting of the root. During the rains of 1912 the surface soil of the shade plots did not contain more than 400 c. ins. of water-free air-space per c. ft. of soil, whereas the soil of the open plots contained considerably less water and more water-free air-space. It will also be seen that, in the shade plots, the water-free air-space was actually less than has been proved to be highly injurious in the same soil in non-porous pots. In the dry season following the rains of 1912 more seedlings died of drought, during the months of least rainfall, in the shade than in the open plots. This was explained by the fact that, although there was practically no difference in the soil-water-content of the open and shade plots, respectively, at a depth of 3–9″ during this period, the roots in the shade had attained, by May 1913, an average length of 6″ only, as against an average length of 18″ in the open. The plants in the open, therefore, having their roots in the deeper moister soil layers were comparatively safe from damage by drought.

Plate III, fig. 1 shows a typical shade plot at the close of this experiment in July 1915. Notice the absence of vigorous seedlings in the seed-bed. Plate III, fig. 2, on the other hand, shows one of the open plots in the same month. Note the numerous healthy plants.

(4) Sowings, in 1913, in large pots filled, some with clean sand alone and others with a mixture of clean sand and dead *sal* leaves, which were sunk in one of the shade plots of the previous experiment resulted in a percentage of 82 healthy plants at the close of the first rains, as compared with 62 per cent. obtained in the adjacent soil from which the dead leaves and humus had been cleared for two years and 16 per cent. obtained in the same soil with which dead *sal* leaves had been mixed. The root development in the sand was also materially better than that in the adjacent soil. As the plants, in this experiment, were exposed to practically identical conditions of light, temperature, and air-humidity, this indicates that the unsatisfactory development of seedlings in the shady forest is primarily due to a soil factor and not to deficient light, unsuitable air-temperature, or air-humidity ; also that the injurious effect is increased by an admixture of dead *sal* leaves with the forest soil and is inoperative in a well drained sand even when dead *sal* leaves are mixed with it. Other experiments have indicated that the effect of this soil factor is progressively diminished by repeated working of the soil coupled with removal of the humus.

With reference to the chief object of the present work, *viz.*, the establishment of vigorous seedlings in the local forests, the experiments detailed above indicated :—

(1) that an injurious soil factor was chiefly responsible for the unsatisfactory seedling development by causing high mortality during the rains and subsequently a high percentage of deaths from drought owing to poor root development ;

PLATE III.

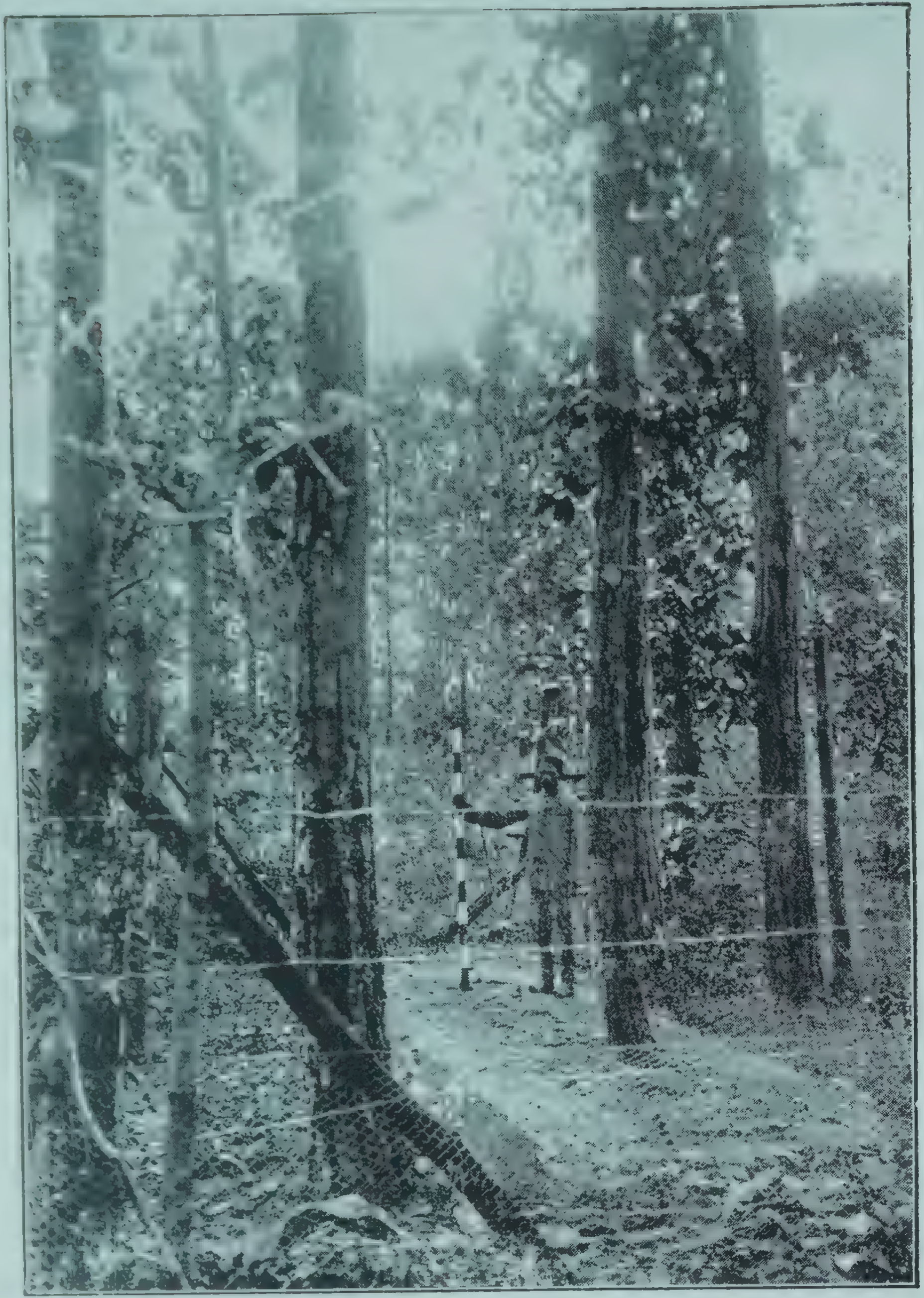


Fig. 1.

Forest shade plot XI. Photograph taken 20th July 1915, 2 years after sowing. Note the absence of vigorous seedlings in the seed-bed.

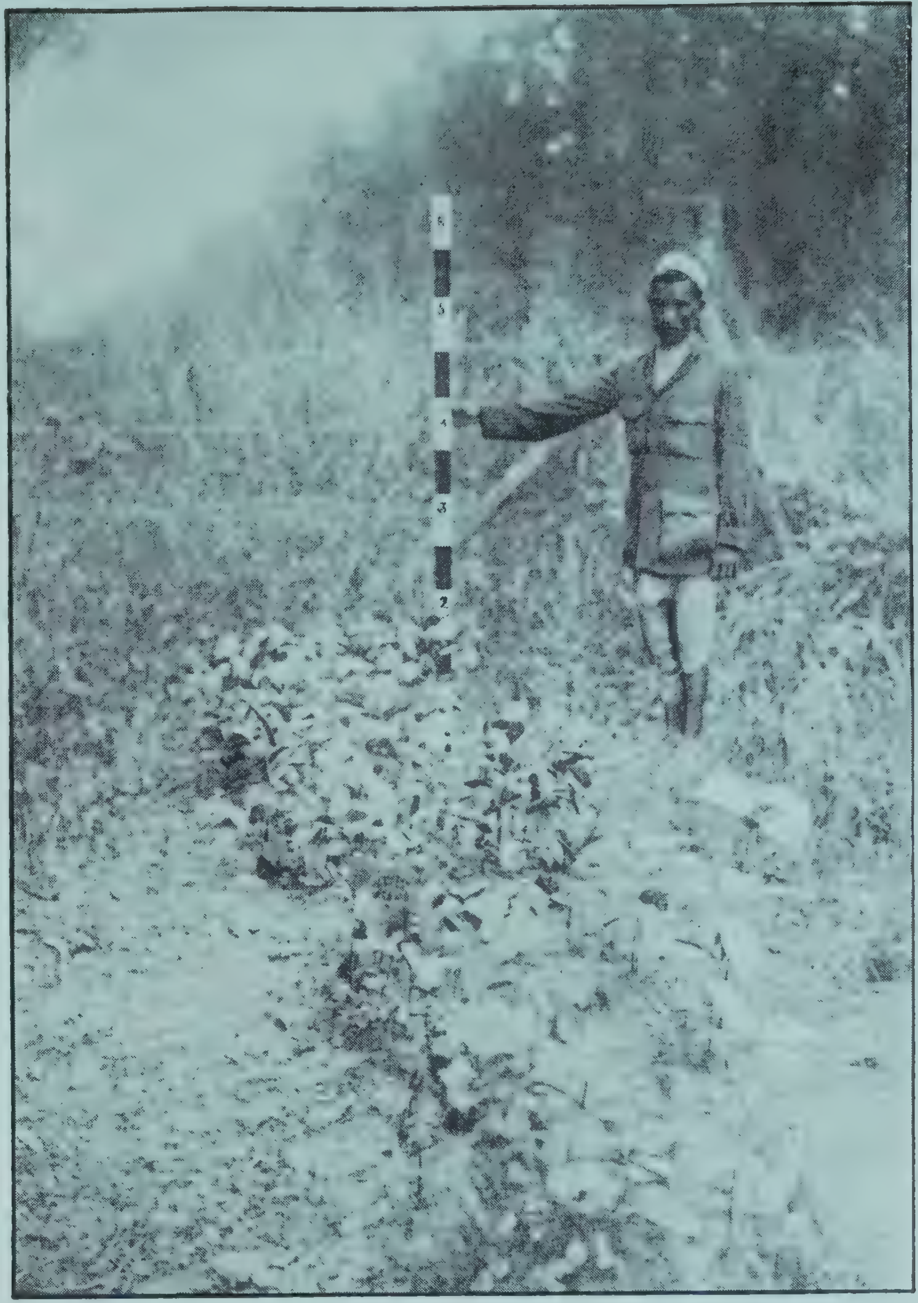


Fig. 2.

Forest plot VIII, in the open. Photograph taken 20th July 1915. Note the numerous healthy 2-years-old seedlings surviving in the plot.

(2) that this soil factor could be put out of action by sufficiently good soil-aeration.

It appeared probable, therefore, that clearing the forest growth and exposing the soil freely to sun and air would produce the soil conditions necessary for successful growth, provided that the area cleared was sufficiently small to ensure the light side-shade necessary in Northern India for protection from frost. In 1913, therefore, two adjacent sample plots were selected in a portion of the Dehra forests where sowings in the previous year had given unsatisfactory results.

Above one plot, the overhead cover was entirely removed, before sowing, by felling all trees above and in the immediate neighbourhood of the plot, the total cleared space having a diameter of 60 ft. or a little less than the height of the surrounding trees. In the adjacent shade plot the cover was kept intact. At the close of two years, the percentage of healthy plants in the shaded and cleared plot, respectively, was 34 and 59, the percentage of the surviving plants which had not died back was 10 and 25, while the average height of the plants was 5″ and 12·4″, respectively. The fact that the ground was worked and dead leaves removed for two years in succession was responsible for the results in the shade being considerably better than usual, but there can be no question as to the marked superiority of the open plot. In the cleared plot also, taking only the 4 best plants (which would be sufficient to stock the area of the plot, *viz.*, 18′ × 3′), their average height was $20\frac{1}{2}''$ which fairly closely approaches the ideal seedling development for the locality which was noted at the beginning of this paper *viz.*, 26″.

Plate IV, fig. 1 shows the shade plot and Plate IV, fig. 2 the cleared plot at the close of this experiment in July 1915.

The conditions necessary for the successful growth of *sal* seedlings, therefore, may be said to have been determined as follows :—

(1) a well aerated seed-bed free of raw humus ;

(2) full overhead light ;

(3) light side-shade sufficient to prevent damage from frost and to keep the soil moist in the dry season.

As regards the identity of the injurious soil factor alluded to, all the facts hitherto ascertained indicate that it can be rendered innocuous by sufficiently good soil-aeration and, for the present, it may be conveniently indicated by the general term bad soil-aeration. It is not at present possible to define it more exactly or to indicate the precise way in which good aeration renders it innocuous. One thing, however, is clear, *viz.*, that the injurious action is not due merely to an excess of water in the neighbourhood of the roots. This has been praved by a water-culture experiment carried out at Dehra Dun during last rains, in which the injurious factor was found to be practically inoperative. In this case, after 75—78 days in the water-culture, only 8 per cent. of the *sal* seedlings died and the average length of healthy root in the surviving plants was 5·9." A simultaneous culture in badly aerated soil for a period of only 67 days resulted in 93 per cent. of deaths and an average length of healthy root of 1" only. Plate V, fig. 1 shows the appearance of the seedlings after 75—78 days in the water-culture and Plate V, fig. 2 shows the root-development of 6 typical specimens.

Other factors possibly concerned are the lack of sufficient oxygen for root respiration and the production and accumulation in injurious quantities in the soil of one or more substances which are directly poisonous to the roots. Further work is required to determine the relative importance of these factors. In the meantime, however, it is interesting to note that Mr. C. M. Hutchinson, Imperial Agricultural Bacteriologist at Pusa, who kindly examined samples of the soils from the corked pots mentioned in the above experiments, has found bacterio-toxins in all of them. These toxins are said to be capable of inhibiting nitrification and of directly injuring seedlings.

In conclusion, it may be noted that the accurate identification of this soil-factor is important for Indian Forestry, not only on account of its effect on seedlings, but also because of its possible action on older trees. There is reason to believe, for example, that, in the wet *sal* forests of Assam and the Bengal Duars which enjoy an annual rainfall of some 200", the intensity of this injurious factor progressively increases with the age of the forest and materially affects the health of the older trees—possibly preparing the way for the attacks of injurious soil fungi and other parasites.

PLATE IV.

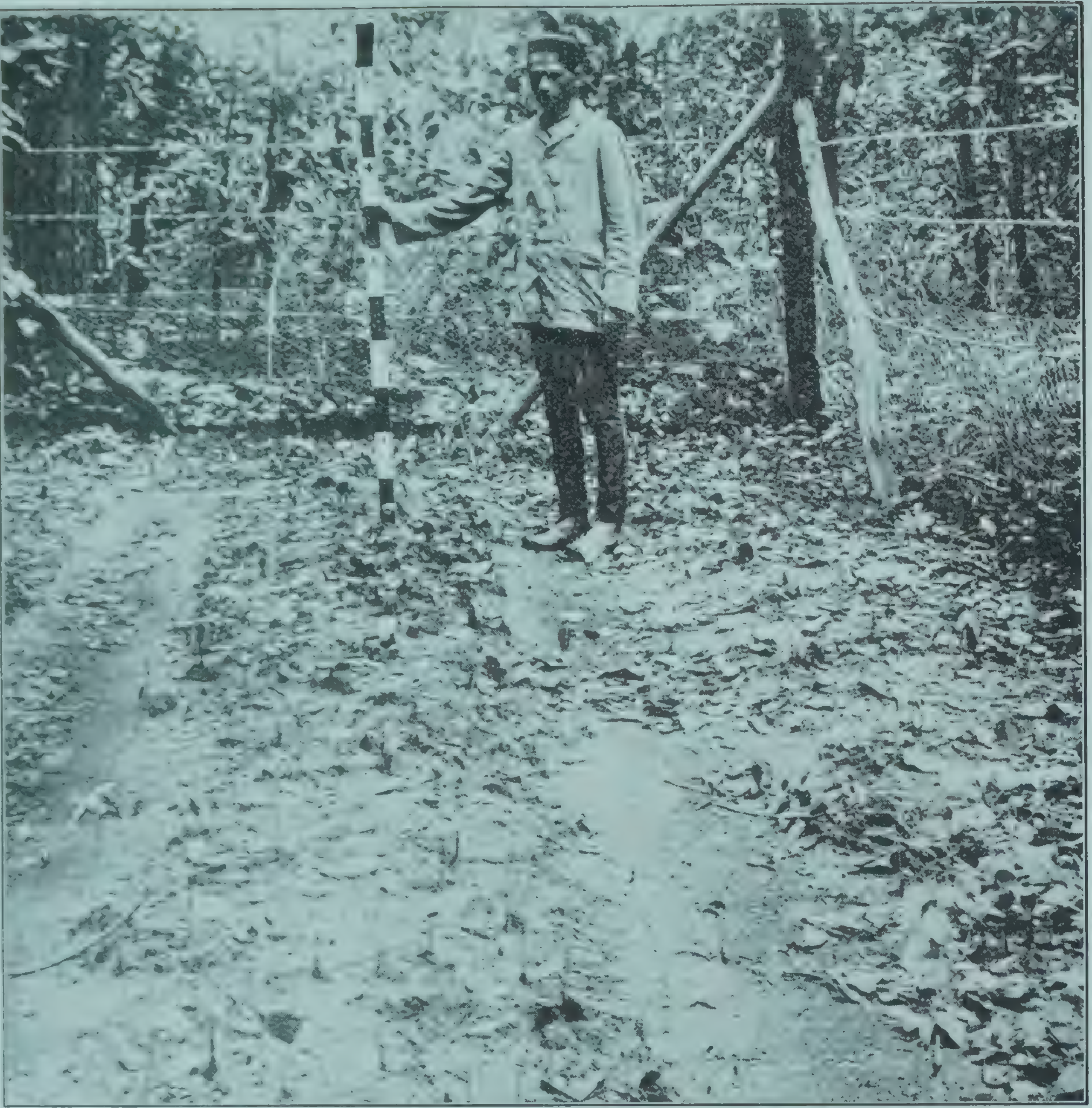


Fig. 1.

Forest shade plot V. Photograph taken 20th July 1915. Note the appearance of the 2-years-old seedlings surviving in the plot.

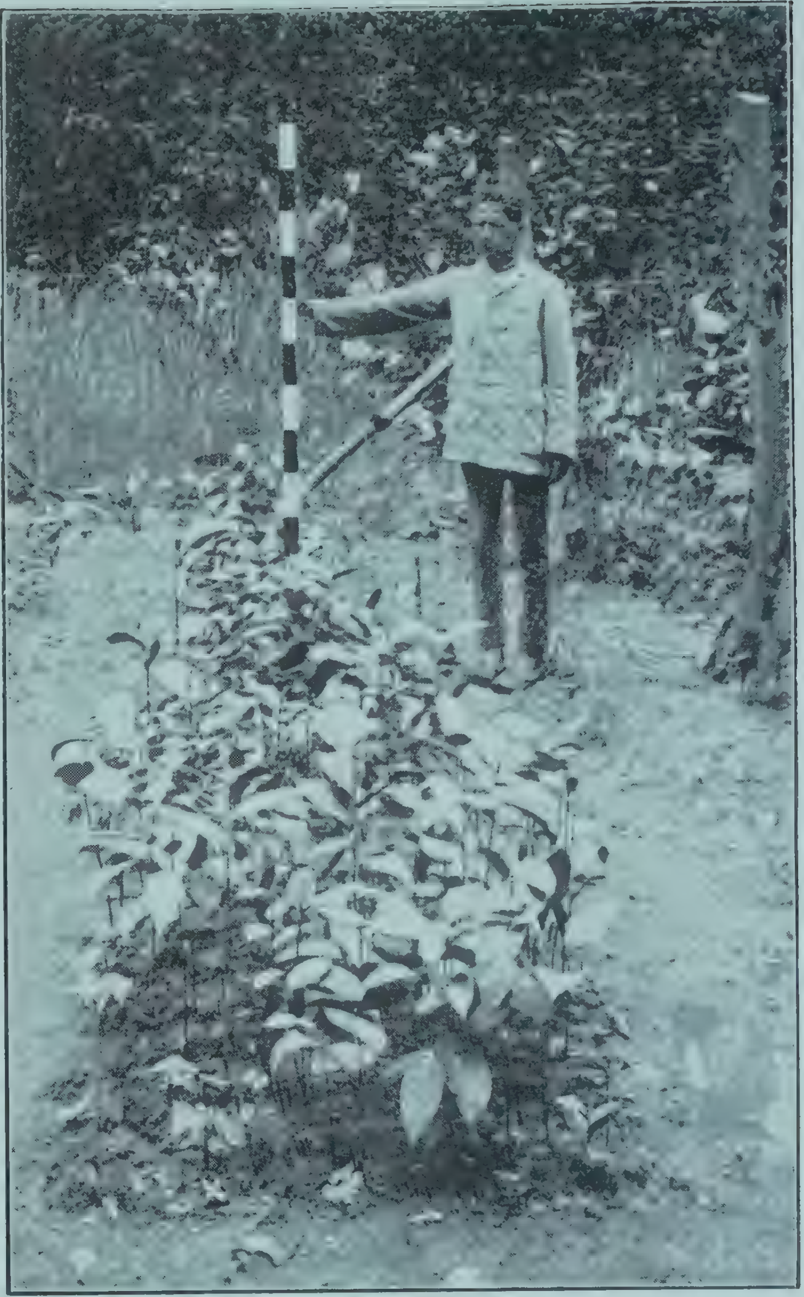


Fig. 2.

Forest Plot IV. An area 60 ft. in diameter was here clear-felled in May, 1913. The photograph was taken on 20th July 1915. Note the vigorous 2-years-old seedlings surviving in the plot.

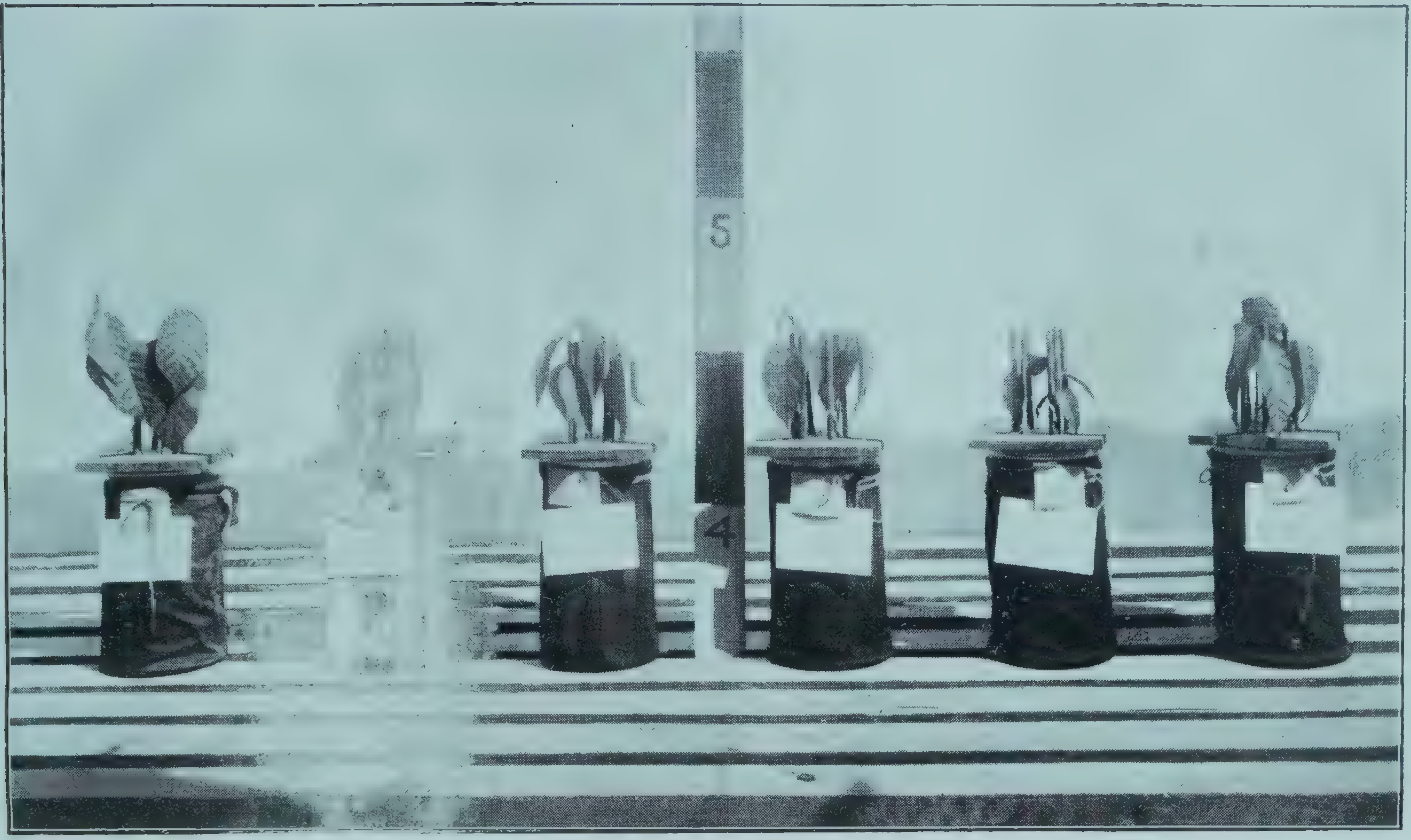


Fig. 1.

Photograph taken 27th October 1915, showing 12 *Sal* seedlings which have been grown continuously in a water-culture solution for a period of 75 (in the case of four plants on the right) to 78 days (in the case of 8 plants on the left.)

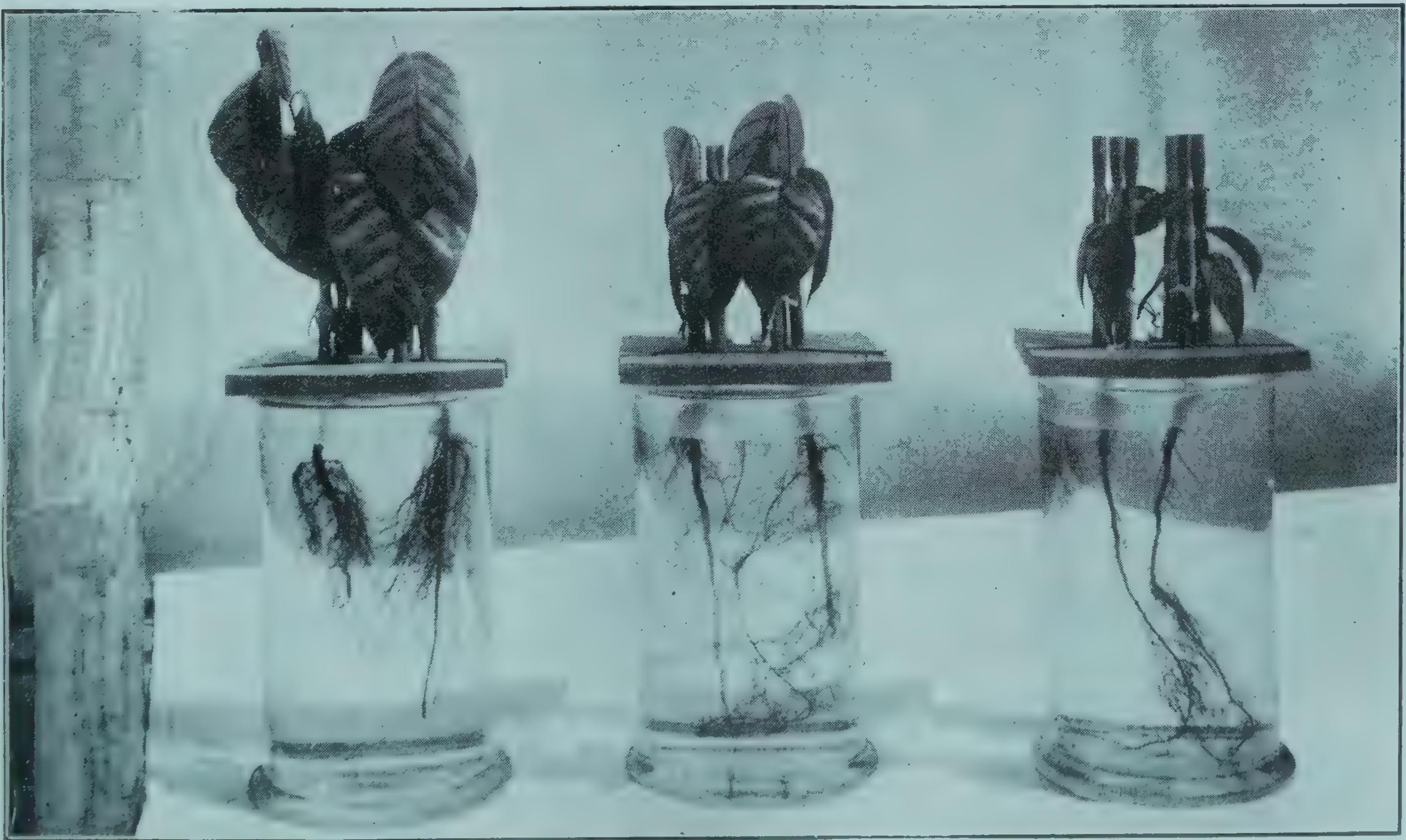


Fig. 2.

Photograph taken 27th October 1915, showing the root-development of 6 *Sal* seedlings which have been grown continuously in a water-culture solution for 78 days, in the case of the 4 plants on the left, and for 75 days, in the case of the 2 smaller plants on the right.

THE RE-ALIGNMENT OF AGRICULTURAL HOLDINGS.

BY

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Most countries with a large peasant population have found it necessary at some time or other to introduce legislation for the re-alignment of holdings to enable the available land to be more economically and efficiently cultivated. The subject has been ventilated from time to time in India but little has been done. It is true that the waste of irrigation water, caused by the present haphazard system, has often been insisted upon, and in the Punjab care has been taken to avoid this on the great new canal systems. Near Poona in the Bombay Presidency the Irrigation Department is now engaged on the squaring up of fields and the drafting of rules to enable greater economy of distribution to be effected on the small, but important, canal systems which are chiefly used for sugarcane. Generally speaking, however, the advocate of re-striping is looked upon as an impatient idealist whose methodical soul is vexed by the present irregular field boundaries.

It has to be admitted that there are great practical obstacles in the way. The present land tenure system of the United Provinces, especially in that portion which comes under the Agra Tenancy Act, makes it exceedingly difficult to alter field boundaries without infringing vested interests. An occupancy tenant possesses cultivating rights in a definite plot of land, which may be only a fraction of an acre in area, and not only can he not be dispossessed, but there is no legal way in which his occupancy rights can be purchased from him except in those cases where land is acquired by Government. Nor is the ownership of land any more simple. Many villages are now owned by a number of petty zamindars whose land is scattered in different parts of the village, so that any arrangement for general betterment by consent is practically impossible. It is obvious, therefore, that progress in this direction could only be made with the aid of special legislation.

The natural obstacles being what they are it is essential to show that the economic benefits to be derived from re-striping are such as to justify the necessary measures. It may be noted, however, in passing, that the present situation is largely the result of legislation undertaken within the last fifty years. The whole of the Indian land tenure system is based on the assumption that all land is the property of the state. The present system of landlords, with the private ownership of land, is a comparatively recent creation following on British rule and based on English analogies. Introduced as it was to save the agriculture of the country from the evils of the system of farming out blocks of land to contractors for the collection of revenue, it has largely justified itself, and the same may be said to be true of the tenancy laws which were introduced to further protect the tenant. It is only natural, however, that legislation introduced to meet pressing political needs should fail to take account of the effect on subsequent economic development. Should it be found that the tenancy laws in their present form are creating a new evil by checking economic development a strong case for their further modification would exist.

The present scattering of parts of a holding in different parts of the village, which is perhaps one of the first things which strikes the student accustomed to the compact farms of the west, is largely a result of the existing scheme of village life. Instead of each tenant residing on his holding it is usual to find all living in a central *basti*, even if it involves journeys of two or three miles for himself and his cattle. The system is wasteful of labour and cattle power and also of manure but has certain advantages. It doubtless arose when the mutual protection of life and property was more essential than at present, but it is unlikely that the present social organization will be greatly disturbed in the near future, though signs are not wanting of a steady tendency to form smaller sub-villages nearer to the fields. While it is doubtless of some advantage to the individual tenant to have his holding spread over the different classes of available land, the system suffers from the disadvantage that there is less encouragement for a cultivator to concentrate attention on handling one class of soil adequately. Were this, however, the only point to be gained by the re-alignment of holdings one would be inclined to allow it to come about gradually as the result of changing social and economic conditions.

The greatest disadvantage of the present system, however, is that it prevents any tract of land from being treated as a whole and general measures taken for its improvement. The greatest limiting factor in Indian agriculture is undoubtedly the water-supply, and it is extremely difficult to take steps to improve existing conditions with the present system of holdings. In canal-irrigated tracts the area irrigated is almost invariably much less than the area commanded by the canal. The main great irrigation sources of the Province have already been harnessed and further development must either take the form of better economy in the use of the existing sources or the exploitation of schemes involving greater working cost and often higher capital expenditure and, therefore, more expensive water. It is commonly accepted that, from the great canals only about one-third of the water reaches the field, and that while some margin exists for the reduction of the amount of water actually applied the main losses occur in the canal channels and in the subsidiary village channels --which share the loss fairly equally. The prevention of loss by seepage from canal channels is beyond the scope of the present paper, but it may be noted in passing that any radical measures in this direction must involve additional capital outlay and, therefore, either a rise in the canal rates or better utilization of the water. The loss in village channels is to a great extent avoidable. At present the village water courses follow field boundaries and are consequently unnecessarily long and tortuous and often undesirably aligned as regards levels. While steady improvement in this direction is being effected through the influence of irrigation officers many of the worst cases cannot be touched. Nor is the situation appreciably better in tracts which depend on wells for their irrigation. The channels from these also are often unnecessarily long and devious, and the scattered ownership of the small fields often puts obstacles in the way of the construction of much needed wells. With more compact and better aligned holdings there would be a greater incentive to the construction of larger wells (or of tube wells) enabling a larger area to be irrigated with less labour. Recent experiments seem to indicate that there is a great future for the employment of oil engines and pumps both on the best masonry wells and on tube wells, but with holdings in their present form, economical distribution of the water is difficult and in many cases so many small interests are involved that it would be difficult to meet them all.

It would be easy to cite many other instances of indirect disadvantages for which irregular field boundaries are responsible, *e.g.*, the absence of decent roadways to give access to the fields, difficulties as regards threshing floors and the carriage of produce and manure, but it is sufficient to say here that they all share one feature, *viz.*, that, except in the case of works undertaken by Government, armed with the powers of the Land Acquisition Act, progress is almost impossible under present conditions.

It is now proposed to consider the effect of present conditions on the actual cultivation of the land. The maintenance of correct levels in a field during all processes of cultivation is recognized in most countries as one of the essentials of good farming. In the Gangetic plain, with an exceptionally easily worked soil, the results of carelessness in this direction are not so readily noticeable, but, on the other hand, the nature of the climate—characterized by heavy falls of rain confined to certain periods of the year and that (in the case of cold weather crops) not the growing season—makes the conservation of rain-water and its correct distribution on the land of vital importance. It being almost impossible to correctly plough a small irregular field, it is not surprising that most cultivators' fields show bad patches which are frequently due to nothing more than faulty levels. The lower patches are water-logged during the monsoon while the higher patches dry out too quickly in the cold weather. Even the best cultivators' fields are frequently saucer-shaped, with the result that there is water-logging in the centre and consequently a poor crop. When any form of iron plough is used to improve the general cultivation, the difficulties are accentuated as the deeper and more thorough the cultivation, the greater the necessity for the maintenance of correct levels. Simple as it may seem, there are few agricultural officers who have not been confronted with this cause of loss of yield at some time or another. The explanation as to why even comparatively slight and temporary local water-logging causes serious loss is probably to be found in the fact that successful cultivation in the plains of India largely depends on the maintenance of a suitable environment for nitrogen-fixing and nitrifying organisms during the monsoon period. Local water-logging during the monsoon, producing temporarily anaerobic conditions, causes a loss of available nitrogen and hence a diminished crop. The experiments carried out by Mr. and Mrs. Howard at Pusa show that not only does the wheat crop on water-logged land yield far less than on properly drained land, but that the result can be partially remedied—but at additional cost—by the application of nitrates. Generally it may be said that the present small and irregular fields common in many parts of this province seriously militate against the adequate conservation of soil moisture and the maintenance of fertility and, therefore, cause direct loss of produce. Further, they discourage the introduction of the more expensive improved ploughs and cultivating implements as it is difficult to work these to advantage in small irregular fields, whereas if the fields were decently aligned there is reason to believe that joint ownership of such implements would be practicable.

In no direction, however, is the need for the re-striping of holdings more clearly seen than in the problems of checking erosion and effecting adequate drainage. The question has been fully dealt with by Howard[1] so that it is sufficient here to deal with its main aspects only. We are so accustomed to think of the plains of India as flat that we are apt to overlook irregularities which, small as they are compared to the hill systems of other countries, are sufficient to be of a great importance in a country of heavy rainfall. As is pointed out by Howard comparatively gentle slopes are sufficient to allow large quantities of the finer particles to be removed from the higher lands to the lower with the result that the physical texture of both deteriorates. The high lands are annually denuded of their finer particles and the fertility and moisture-retaining capacity adversely affected. The low lands, constantly receiving the run-off from the high, are annually receiving unneeded additions of fine silt thus becoming heavier and less workable and in addition receive an excess of water preventing adequate cultivation in the rains and causing a direct loss of fertility. Figures are published in the Cawnpore Farm Report for 1915 which show that the introduction of suitable catch drains on an area of this type has made it possible to raise a normal good crop of wheat on land that a few years ago had to be thrown out of wheat cultivation on account of the water-logging that took place in the rains. On a larger scale the recently opened Kalianpur Farm provides an example of a piece of land, previously only barely culturable, which has been converted into a good farm by proper terracing and correct laying out ; the capital value of the land, as judged by its yielding capacity, has trebled in about 5 years. Operations of this nature, however, require control over a considerable area. Given this control it would not be difficult, nor unduly expensive, after a proper survey to lay out most villages with proper drains and banks to stop erosion and prevent water-logging of the low areas, providing suitable roads, footpaths and proper irrigation channels. At Kalianpur indeed it was found possible to make the channels serve the double purpose of catch drains and irrigation channels. Under present conditions, however, it is impossible to carry out alterations of this kind unless the land is the property of Government or, in rare cases, of a single individual.

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[1] Howard, A. Soil Erosion and Surface Drainage. *Bulletin* No. 53 *of the Agricultural Research Institute, Pusa.*

Finally, in the case of one crop at least, the present lay-out of the average village hampers economic development and prevents the cultivator from getting a fair price for his produce. There are many tracts in this province where the grower would willingly sell his sugarcane to a factory at prices more favourable to the factory than obtainable in most cane-growing countries. But the small scattered holdings often make the transport problem insuperable although sufficient cane is already grown within a reasonable radius and more would be grown if a factory could be started. As a result the cane grown is not economically utilized and extension of cane cultivation is checked. In the writer's opinion the present tenancy system has a great deal to do with the comparative shyness of capital for enterprises of this nature.

It is realized that drastic legislation such as would be necessary to permit of the re-striping of holdings requires a strong public opinion to support it, and it is, therefore, suggested that the first step would be to acquire a few villages in different parts of the Province, carry out the necessary alteration, and re-let the new holdings to the original tenants as nearly as possible. An object lesson of this kind would soon convince the land-owning classes of the need for general measures and, pending legislation, some of them might be able to assist in carrying out partial schemes in their own property.

If any excuse is needed for bringing before a science congress a matter of purely economic importance it seems sufficient to say that the existing land tenure system of this Province imposes a limiting factor on the application of scientific method to agricultural improvement.

SCIENTIFIC METHODS IN AGRICULTURAL EXPERIMENTS.

BY

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Having had occasion recently to collate the results of a large number of field experiments conducted throughout India and having had some difficulty in drawing anything but vague general conclusions from them, it occurred to the writer that a plea for more scientific planning and execution of such experiments might not be out of place.

The Rothamsted experiments seem to have been taken perhaps too much as a model on which experiments in India should be planned rather than as supplying a basis of information to be utilized in devising experiments more particularly suited to Indian conditions.

The information provided by the Rothamsted experiments is of two kinds, relating, firstly, to the reaction of the Rothamsted soil, and of the crops grown there to different manurial applications, and, secondly, to the wider subject of field experiments generally.

Little need be said about the first of these aspects except as regards certain limitations to the direct application of the results to conditions other than those under which the experiments were tried.

These results have proved that the application of manures containing nitrogen and the elements found in plant ashes, in quantities of the order of magnitude in which these elements are removed in crops, has a marked influence direct or indirect on the production of crops.

They have shown also that by a continued application of a manure complete in all but one of the important ash elements, the productive capacity even of land that contains enormous reserves of that one element may, by the removal of the crops grown, be reduced, in a comparatively small number of years, to very much below normal. And they have shown how rapidly nitrogen may be accumulated by the growth of leguminous crops, provided that a moderate supply of these ash elements in a soluble condition is maintained.

But while a foundation for local investigations has thus been provided, in the principle of supplementing the weakest links in the chain of chemical elements on which fertility depends, by a supply of the deficient elements in a soluble form, no attempt has been made at Rothamsted even to illustrate by local example, the solution of what must always be a local economic problem—that of adapting agricultural practice so as economically to extract from the insoluble reserves in the soil, and maintain in a relatively available form, sufficient proportions of the principal elements required by crops.

The cropping of Rothamsted has been purposely exhaustive, and manures have been freely supplied from outside ; no attempt has been made to make the most economical use of the reserves of plant food existing in the soil, the full utilization of which must always be, in greater or less degree, an object of agricultural practice.

The importance of this point is shown by the rapidity with which the available potash was exhausted at Rothamsted, on a plot which received a manure containing all the other essential elements of plant food ; and this, although the soil when completely broken down by hydrofluoric acid, was found to contain over 2½ per cent. of potash. Mr. Taylor at Sabour has similarly found over 6 per cent. of potash (over 8 tons, per inch depth, per acre) in a soil from Ranchi—where, nevertheless, ashes form one of the chief manures.

Now India is a poor country, and cultivators cannot afford to import over the long distances into the interior, any great quantity of heavy manures ; or to use, as manure, what might otherwise be fed to cattle ; while on the other hand the relatively rapid weathering and denudation due to climatic extremes brings within reach of the surface every year, a relatively large quantity of fresh subsoil for exploitation by plants.

Looking through a large number of experiments it appears that while much labour has been spent on testing the commoner commercial manures, comparatively little has been spent on attempting to get the most out of the soil by particular study of its constitution and reaction to special treatment.

Moreover the special value of leguminous crops as subjects for experiment under the conditions just described, hardly seems to have been taken into account in designing experiments in India.

Another limitation, and possibly a very important one, to the utility of the particular results obtained at Rothamsted in designing experiments in India, is the fact that chlorine and sulphur are supplied in excess of the demands of crops at Rothamsted by rain ; owing perhaps to the comparative proximity of the sea, and to the large consumption of coal in England, and to the even distribution of the rainfall. The writer is not aware of any published figures relating to this point in India, but recent experience at Ranchi of the very remarkable effect of small quantities (10 to 40 lb. per acre) of sulphur, and of gypsum, on groundnuts, indicates that sulphur at any rate may sometimes be a limiting factor on high-lying well drained soils in Peninsular India which are subject to leaching by heavy rainfall. Under such circumstances the use of sulphur or of gypsum on control plots, in experiments with sulphate of ammonia or superphosphate, is essential if reliable information is to be obtained.

But the intention of this paper is not so much to point out particular differences between English and Indian manurial problems as to indicate the necessity for independent scientific surveys of local requirements before planning experiments, and to suggest that the use of the classical experiments at Rothamsted to investigators elsewhere, lies rather in the lessons that have been drawn from them as regards agricultural experimental methods in general than in the direct application of the methods employed there.

From this point of view the value of the Rothamsted experiments lies in the number and reliability of the statistics obtained.

Examined in the light of statistical science these figures have demonstrated the very considerable magnitude of the 'experimental error' in field experiments conducted under the most favourable conditions; and, though it is now some years since this was pointed out, there is little evidence that the lesson has been taken to heart in laying out field experiments in India.

Hall in an article in the *Journal of the Board of Agriculture* in August 1909, quoted an instance of the yield of two unmanured grass plots one of which gave, on the average of 50 years results, 10 per cent. more than the other; but frequently gave over 30 per cent., and on one occasion 96 per cent. more; and on two occasions over 20 per cent. less.

In a subsequent paper in the *Journal of Agricultural Science*, October 1911, Hall and Mercer showed that the most careful methods of growing, harvesting and weighing plots of mangolds and wheat, under apparently uniform conditions, gave results that were subject to 'probable errors' sufficiently great to make comparisons of the results from a single pair of plots worthless for most purposes. They recommended that for practical purposes in any field experiment each unit of comparison should be given five plots of one-fortieth of an acre each, systematically distributed within the experimental area.

The authors attached considerable value to the scattering of plots throughout the area and showed that the shape of the plots had (as indeed would be expected) in itself, no appreciable effect in reducing the error. But in an appendix to their paper, one who signed himself 'Student' showed how considerably the error could be reduced by having the plots for comparison relatively long, narrow, and alongside one another. By dividing squares into pairs of plots for comparison, less than two-thirds of the area was required to obtain the same accuracy as by random comparison in the case of roots, and in the case of wheat, less than half.

These results, depending chiefly on avoidable or unavoidable physical differences between the plots, are, of course, not quantitatively applicable to conditions other than those under which they were obtained. But the principle is of greater importance in proportion as the effective control of the experimental area is less, and is probably therefore more important under the conditions obtaining on most experimental farms in India than it is at Rothamsted where minor variations in the soil are less accentuated by extremes of rainfall or drought, and where the work was laid out on land carefully selected for uniformity in the light of a previous known history.

Yet on how many farms in India are even the five plots recommended by Hall and Mercer considered necessary for each comparison ; and, where only two, or at most three plots are used, what results worth having can be obtained in the limited number of years over which a consistent policy can usually be maintained ?

Acting on the principles that have been emphasized, the writer made an attempt during the last monsoon to throw some light on the manurial problems of Chota Nagpur, where immediate results were required to supply an existing organization with material for propaganda.

The conditions were unfavourable, the farm at Ranchi was started in May 1915, the land being then uncultivated. The best land that could be selected was not by any means uniform, as it was intersected by low terraces and was being carted over by building contractors. Inequalities had to be ignored ; carting was stopped ; and six acres were divided by low ridges at right angles into 60 plots, each 40 links wide by 250 long.

Analysis of the soil having shown a marked deficiency of lime and phosphoric acid, and only a trace of sulphur, it was decided to devote the whole 60 plots to quantitative tests of the effect on groundnuts of lime, sulphur, and bonemeal—the latter being used only because raw mineral phosphates were unobtainable owing to freight difficulties. The general scheme was based on the division of the area into series of plots for testing the different manures, alone and in combination; test and control plots being alternated throughout. In comparing the results, the weight of produce of each variant plot was compared with the sum of the weights from the control plots on either side of it.

The details of the results, which will be published in the Farm report, are of no particular interest, except in the case of sulphur, to which reference has already been made.

The effect of sulphur was quite phenomenal and would have needed no duplication of plots for its detection, even when only 10 lb. per acre (costing 12 annas) was applied. Slaked lime, in all quantities up to 5,600 lb. per acre, was also markedly beneficial.

But the general character of the results is best illustrated by those given by bonemeal. This manure gave a markedly increased yield in each of 5 plots to which it was applied without lime, but when applied in addition to 4,000 lb. of slaked lime per acre it gave a relatively much smaller increase in 6 out of 7 plots, and this increase had again to be discounted by a decrease of 20 per cent. on the seventh plot—a discrepancy clearly due to 'experimental error,' of the importance of which in this case it gives some idea. If the number of plots had been much smaller, either the significance of the results might have been overlooked, or the discrepancies might have led to their rejection as inconclusive. As it is, conclusions have been drawn which, while showing weak points in the original plan of the experiments, have both enabled immediate recommendations to be made to cultivators, and have provided a solid basis on which to plan a new set of experiments for next year.

THE IMPORTANCE OF SOIL VENTILATION ON THE ALLUVIUM.

BY

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I. Introduction.

The dominant factor in the internal economy of the Indian Empire is the monsoon. The well-being of the people, the commerce of the country and the revenue collected by Government all depend on the amount and distribution of the summer rainfall. It is not surprising, therefore, to find that the attention of the agricultural investigator in India tends to be concentrated on questions relating to the supply of water to crops. At the same time, the other factors on which yield depends are apt to be obscured and crop-production comes to be regarded almost entirely as a question of water-supply. After ten years' observation of the crops grown on the Indo-Gangetic alluvium, during which a good deal of first-hand experience in agriculture has been obtained at Pusa in Bihar, at Lyallpur in the Punjab, and at Quetta in Baluchistan, the conclusion has been reached that a full supply of air in the soil is quite as important as a sufficiency of water. While air is a necessary raw material for the roots of plants wherever they may be grown, efficient soil ventilation is found in practice to be particularly difficult on alluvial soils like those met with over large areas of the plains of India. Alluvial soils, like those of the valleys of the Ganges and Indus, pack very readily and always run together on the surface after heavy rain forming a well-defined crust, well-known to any cultivator as the *papri*. Two chief factors are responsible for the ease with which these soils form surface crusts after light showers and lose their porosity altogether after long continued rain. In the first place, the soil particles are small in size and exhibit no very great range in diameter and, in the second place, much of the rain comes in heavy continuous torrents quite unlike anything experienced in temperate regions.

Defective aeration of the soil, besides interfering with the respiration of the active cells of the root and of the soil bacteria, exercises a profound influence on the development of the root-system itself. Where the subsoil is wet and consolidated and gaseous interchange between the soil and the atmosphere has been checked, crops are found to develop superficial roots only and are then particularly liable to the harmful effects of drought. To withstand any shortage of moisture, to make the most of the brief growing season and to ripen the crop before the onset of the hot weather, the root-system of all *rabi* crops must be deep. In the *kharif*, long continued and heavy rain, by destroying the porosity of the soil and by thus interfering with the air supply to the roots and to the soil organisms, leads to a wilted, poverty-stricken condition of the crops and to a diminished yield. Such examples of damage to monsoon crops, caused by excessive rain interfering with aeration, were common in many parts of the United Provinces during the later phases of the 1915 monsoon.

II. Some Examples of Soil Ventilation.

Among the numerous instances observed of the effect of improved soil-ventilation on the growth of crops it will be sufficient to quote a few examples.

1. *The yellowing of peach trees.* As the summer progresses at Quetta, the foliage of many of the peach trees alters in colour and changes first to light-green and finally to yellow. Premature leaf-fall then takes place and, by the end of August, many of the branches are almost bare of leaves. In addition to the yellowing of the foliage, two other symptoms manifest themselves. The wood gives off large quantities of gum and the ripening fruit is deficient in flavour. Peach trees affected in this way die out in two or three

years, the process taking place in stages by the death of one or two large branches at a time. Investigation of the trouble showed that this unhealthy condition was not caused by want of available nitrogen in the soil and was not a real disease of the nature of the "peach yellows" of the United States. Buds taken from affected trees produced healthy plants and therefore the unhealthy condition was not transmitted in propagation. Yellowing was found to be reproduced at will, either by deep-planting or by over-irrigation. Any effective method of soil-aeration was found to transform affected trees into a healthy, vigorous condition in a single season. Yellowing and the premature death of the peach trees at Quetta was therefore found to be the result of defective aeration of the soil caused by excessive surface-flooding under arid conditions. The affected trees naturally carried a load of parasites such as scale insects and a certain number of fungi but with the resumption of healthy growth these pests gradually disappeared.

2. *Soil-aeration and green-manuring.* The provision of some cheap form of organic matter is one of the great needs of Indian agriculture at the present time. As is well known, the amount of manure available is small due to the fact that most of the cow-dung is burnt as fuel and almost all the *bhusa* is used for feeding cattle. As a rule, Indian soils are deficient in organic matter and the yield is limited by this factor. One theoretical method of making up the deficiency is by green-manuring but, in practice, difficulties arise. A considerable amount of attention has been paid to this subject in the Botanical Area at Pusa and the conditions necessary for the success of this operation have now been worked out. If a crop like *sanai* (*Crotalaria juncea*) is raised on the early monsoon rains and ploughed in during July, it is found that the texture of the soil is improved and, in a few cases on light land, the succeeding *rabi* crop benefits enormously by the addition of the organic matter left by the decay of the green crop. In the majority of Bihar soils, however, these results are not obtained and the *rabi* crops following green-manure are much worse than those raised on ordinary fallowed land. As a rule, green-manuring leads to a diminished *rabi* crop although the process results in the addition of a considerable

amount of organic matter to the soil. After some years' experiment, it was found that the factors on which success in green-manuring depends are connected with the air-supply in the soil. If the land is surface-drained and, if provision is made so that each field is protected from the run-off of other areas by a suitable arrangement of trenches, the effect of a green-manure crop is materially increased. If, in addition, the land is subsoiled to a depth of twelve inches before the *rabi* crops are sown, still better results are obtained. When broken tiles (*thikra*), at the rate of about 50 tons to the acre, are mixed with the upper six inches of soil, the results are exceedingly striking and a maximum crop can easily be obtained by green-manuring alone.

The simplest explanation of these results appears to be connected with the part played by air in the soil. The soil is usually regarded as a mass of small particles, arranged in various ways according to the degree of consolidation, with free spaces between these bodies known collectively as the pore-space. Surrounding the solid particles are films of water of various thicknesses while the rest of the pore-space is taken up by the soil-air. The proportion of the pore-space filled by water and air naturally varies with the general wetness or dryness of the soil. The closeness of packing of the solid particles varies greatly, after a crop is sown, as a result of consolidation by irrigation water or rain. In the water films round the particles, there is intense biological activity. Numerous bacteria are rapidly reproducing themselves while the root-hairs of the crop are competing with these soil organisms for water and inorganic food materials. All the protoplasm of these organisms is actively respiring and, in consequence, there is, in the water films round the particles, a keen struggle for oxygen and a great development of carbon dioxide. Under such circumstances, it is easy to understand how it is that analyses of the general soil-air often show a high proportion of carbon dioxide and a comparatively low percentage of oxygen. We must now consider what is likely to happen if this normal struggle for dissolved oxygen in the soil between the roots of the plant and the soil organisms is complicated by the sudden addition of a green crop like *sanai*. In the first place, the growth of the green crop itself will naturally lead to a considerable pollution of the soil atmosphere by carbon dioxide. As soon as it is ploughed in, decay begins and an enormous quantity of oxygen is used up in the process which is by no means complete when the sowing time of a *rabi* crop comes round. The partly decayed organic matter adds a new competitor in the struggle for oxygen. It is easy to understand how the remains of the green crop might easily use up the oxygen in the pore-spaces and load the soil atmosphere with carbon dioxide to such an extent as to poison the air dissolved in the water films. Oxygen starvation and carbonic acid poisoning would affect the plant and growth would be checked. If we improve the aeration by drainage and by adding *thikra,* the decay of the green crop would be hastened and the air-supply of the soil during the succeeding *rabi* crop would be increased to such an extent that oxygen would no longer be a limiting factor.

The nodules of leguminous plants. The copious aeration of the soil in which leguminous crops are grown is perhaps more important than in any other class of cultivated plants. These crops require nitrogen for their nodules as well as oxygen for the respiration of the roots themselves. Once these facts are realized, it is easy to understand the distribution of leguminous crops in India and the agricultural processes in vogue in their cultivation.

The distribution of the gram crop closely follows the occurrence of well-aerated soils. It is only grown under irrigation where the soil is particularly porous or where there is a well-drained and well-aerated subsoil as occurs in many parts of the Bombay Presidency. If an attempt is made to grow this plant in stiff, heavy land, such as the low-lying loams of North Bihar, the result is disastrous. The plants only form roots near the surface and hardly any nodules are produced. The yield is scarcely more than the seed sown. Similar results are obtained under canal irrigation in the stiff loams in the Canal Colonies of the Punjab and other tracts of India. Heavy rains during the cold weather often destroy this crop simply by forming impervious surface-crusts and cutting off the supply of air to the nodules and roots.

In the growth of *rahar* (*Cajanus indicus*) in those tracts of India where the monsoon rainfall is heavy, the best results are obtained by digging the soil between the plants after the monsoon. Heavy rains consolidate the fine alluvium and the digging is necessary to restore aeration. In a similar manner, the Java indigo crop will only form seed in Bihar when the copious aeration of the roots is provided for. The slightest interference with the air-supply soon makes itself manifest by leaf-fall and by the shedding of flowers without setting seed.

III. The Maturation of Crops.

Besides its influence on the actual growth of crops, the provision of an abundant air-supply appears to be bound up with the ripening processes and with the development of quality.

In the case of the wheat crop, the best grown samples are always produced in tracts like the Meerut Division of the United Provinces or on the black soils of Central India, where the soils are naturally highly porous. In Bihar, Oudh, and in parts of the Punjab, where the natural porosity is not so great, the grain is always much thinner in appearance particularly in years when the rainfall is heavy during the ripening period. Unless the wheat roots get plenty of air during the process of maturation, the sample is always relatively poor.

Anyone who has studied the peach tree and has attempted to grow this fruit to perfection must have been impressed by the difference in quality of the same variety when the peach is grown on soils a little heavier than the normal. As is well-known, the peach thrives best on open soils and is particularly sensitive to any form of water-logging. Some years ago, the Botanical Section at Pusa achieved a local reputation on account of the excellence of the peaches grown there. The varieties were only country kinds but they were grown on high land containing a fair proportion of broken tiles (*thikra*). The soil was thus highly porous and the roots obtained abundance of air. The quality of the fruit was excellent compared with the produce of similar trees on land close by a little heavier in texture which contained no *thikra*.

In the growth of vegetables and flowers, some of the soils of Lucknow are famous. The best produce is raised under irrigation on the highly-manured sands near the banks of the Gumti. The soils in themselves are poor but, when properly manured and watered, their porosity is so great that surface-flooding causes little or no damage to its texture. The roots of the vegetables and flowers thus obtain abundant air and grow to perfection. The vegetables have excellent taste while the flowers easily form a quantity of good seed. Here again the development of quality seems to be closely associated with soil-aeration.

A similar result is seen in tobacco growing in Bihar. The best tobacco is grown on high, light lands which have been manured with indigo *seeth.* The *mahajans* pay more for such produce and several of the indigo factories have a reputation for their tobacco. *Seeth* is undoubtedly a most efficient aerating agent and all the experience obtained at Pusa in the growth of the tobacco crop points to the supreme importance of soil-aeration in the ripening of this crop. Once more, quality appears to be closely bound up with the ventilation of the soil which again appears to be of supreme importance in the process of maturation.

R

THE DYEING VALUES OF SOME INDIGENOUS DYE-STUFFS.*

BY

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I.

Natural dye-stuffs are perhaps not as bad as they have come to be regarded since their displacement by coal-tar colours. India boasted of a comparatively well developed art of dyeing in the earliest stages of the historic period. The ancient Indian dyer could dye some very good colours with the help of colouring matters derived from the natural and mineral kingdoms. Some of these colours were fast in every sense of the word and answered all the requirements of the people for whom they were intended. This points to the possibility of valuable colouring matters lying unknown or forgotten in the forests and jungles of this country.

A large number of woods containing red and yellow colouring matters are still used even in Europe but all these are obtained from America. There are undoubtedly similar woods in this country but so far no systematic investigation seems to have been made.

If America can find a market for so many dye-stuff extracts made from woods and other natural products, surely we with our vast, varied, and plentiful natural resources ought to have little difficulty in finding out and placing on the market similar products.

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* Of the two papers printed here only the second was contributed to the Indian Science Congress. The first was published by the Board of Industries, United Provinces, before the Congress was held. It has, however, been reprinted here as the second paper is in continuation of it.

This question is of special importance at the present moment. The stoppage of the supply of German dye-stuffs has caused grave inconvenience in all colour-using industries. If Indian dye-stuffs had not been entirely discarded the distress would not have been so acute. At least some part of the world's requirements would have been met by the dye-stuffs indigenous to this country.

Colouring matters are widely disseminated in the vegetable kingdom. Some one has said that any one who wishes to spin, dye and weave his own raw material at his own fireside need not go far afield for his colouring matters.

Such is indeed the case in a great many places where cottage industries still flourish. In Donegal, famous for its homespun tweeds, the colouring matters used are still mostly derived from lichens and roots. The colouring matters of Donegal possess great fastness and beauty and their methods of application are alike novel and interesting.

I visited Donegal in December 1909 and submitted to the Secretary of State for India a report on the subject of the cottage industries of the congested districts of Ireland. I have alluded in this report to the processes of dyeing used in Donegal.

The following investigation into the dyeing values of certain natural colouring matters still used by native dyers was undertaken under the orders of the Director of Industries, United Provinces.

The colouring matters were tried on wool and cotton by some of the more important methods of modern dyeing.

The methods employed were as follows :—

A. On Wool.

(*a*) Dyed in an infusion of the colouring matter without the addition of any chemical or assistant to the dye-bath.

(*b*) Dyed in an infusion of the colouring matter with the addition of 4 per cent. acetic acid.

(*c*) Dyed as in (*b*) and after-treated in the same bath with 2 per cent. potassium bichromate.

(*d*) Dyed in an infusion of the colouring matter on wool which had been previously mordanted with bichrome and oxalic acid.

(*e*) Dyed in an infusion of the colouring matter on wool which had been previously mordanted with aluminium sulphate and tartar.

B. ON COTTON.

The cotton was steeped overnight in a decoction of myrabolans, next morning it was taken out, squeezed and without washing worked in fresh baths containing the following :—

(*a*) Tartar emetic.
(*b*) Stannous chloride.
(*c*) Alum.
(*d*) Ferrous sulphate.

Generally speaking all the dye-stuffs described hereafter gave the most brilliant results on stannous chloride ; tartar emetic and alum coming after that. Ferrous sulphate, as might be expected, dyed grey to black shades.

The inquiry has so far been prosecuted in regard to the following colouring matters :—

(1) HARSINGHAR. (*Nyctanthes Arbor-tristis*).

The flowers of this tree contain a beautiful yellow colouring matter. The tree is found in abundance in the United Provinces and when in bloom yields large numbers of flowers which generally open at night and fall to the ground in the morning. The flowers are collected, dried, and afterwards sold to dyers.

The colouring matter contained in the flowers is soluble in water, also in alcohol. An extract can therefore be easily made.

Harsinghar gives brilliant yellow shades with all mordants on wool. On wool mordanted with bichrome and oxalic acid previous to dyeing a beautiful brown is obtained. The dyeings on wool possess good fastness to milling with soap and soda.

(2) TUN. (*Cedrela Toona*).

This tree is said to occur largely in the sub-Himalayan forests. The colouring matter is contained in the flowers which are dried and sold. The principal constituent of the flowers is a yellow dye.

Tun dyes the best shade on wool in conjunction with mordant A(*d*). The dyeings on wool are, however, not very fast to milling with soap and soda.

(3) TESU OR DHAK. (*Butea frondosa*).

This tree is found in abundance all over the United Provinces. The dye extracted from the flowers is still largely used by villagers for sprinkling on their persons as a mark of festivity at Holi festival, about which time the tree is in full bloom. The dried flowers are, however, available throughout the year. The flowers contain a yellow colouring matter.

Tesu dyes on wool shades varying from brown to dull crimson according to the mordant used.

The dyeings are fairly fast to milling.

(4) HALDI OR TURMERIC. (*Curcuma longa*).

The plant which yields *haldi* is grown all over the United Provinces. *Haldi* is a dried rhizome or tuber and is a well-known constituent of curry powder. It is largely used as a spice and can be had in any quantity in the bazar. It contains a brilliant yellow colouring matter which however possesses the serious drawback of being changed into red by soap or by alkalis.

The colouring principle of *haldi* is called *curcumin;* it is sparingly soluble in cold water, more freely in hot water, and completely in alcohol. The use of turmeric paper in analytical chemistry is well known. Paper saturated with a solution of turmeric is changed to a reddish brown colour by alkalis; while its reaction with boric acid is still more characteristic. Turmeric paper on being moistened with boric acid and dried becomes brownish red which colour is changed to blue or green by caustic soda.

On wool the best shade is obtained on chrome mordant A(*d*). The fastness of the dyeings on wool is fair.

(5) ARUSA. (*Adhatoda vasica*).

The leaves of this plant yield a yellow colour. *Arusa* is an ever-green plant and is found in the United Provinces. The colouring matter in *arusa* is soluble in water and also in alcohol. The leaves contain a large amount of chlorophyl which is extracted along with the yellow colouring matter. The chlorophyl considerably dulls the dyeings obtained with *arusa*. The yellow dye was separated by adding water to an alcoholic extract of the leaves. The chlorophyl was thereby thrown out of solution and the yellow colouring principle was obtained in the filtrate. This gave much better results in dyeing. On wool the best shade is obtained on chrome mordant A(*d*). The fastness of the dyeings on wool is fair.

(6) NASPAL OR POMEGRANATE RIND. (*Punica granatum*).

This plant is well known for its fruit. The rind of the fruit contains a tanning substance and also a yellow colouring matter, the latter in much smaller quantity than the former.

Pomegranate rind dyes very good shades varying from yellow to full brown on wool. All these possess very good fastness to milling.

(7) JANGLI NIL OR WILD INDIGO. (*Tephrosia purpurea*).

This is a small woody annual occurring in abundance in the United Provinces. It does not contain any substance yielding indigo and its name " Jangli Nil " is probably due to its similarity to the indigo plant.

Clarke and Banerjee have examined the constituents of the leaves of this plant. They found in it a colouring principle allied to quercetin or quercitrin (vide *Trans. Chem. Soc.* 1910, V. 97). Owing to the difficulty of separating the yellow principle from the chlorophyl, efforts to obtain a pure yellow from *Tephrosia* have only been partly successful. The colouring matter is, however, of great value, as it yields dyeings which are comparatively fast to light, washing, and milling. The yellow principle was separated by extracting the dry leaves with alcohol, diluting the extract with water, and washing away the chlorophyl with petrol. The purified colouring matter gave excellent shades of yellow in conjunction with various mordants. On account of the abundance of the plant it may be worth while devising a suitable process for extracting the yellow colouring principle. It would no doubt be very welcome wherever fustic and quercitron bark are still in use. A decoction of the leaves of *Tephrosia* dyes wool mostly dull brown shades in conjunction with the various mordants, the most brilliant shade being that on tin mordant. The dyeings, however, possess very good fastness to milling.

(8) SAFFLOWER OR KUSUM. (*Carthamus tinctorius*).

The dried flowers of safflower plant contain a colouring matter which before the introduction of coal-tar colours was highly prized all over the world. It produces on cotton beautiful shades of red varying from a full crimson to the most delicate pink. Safflower is rather an interesting material. It contains two distinct colouring matters, viz. (1) a yellow soluble in water which is by far the larger constituent, and (2) a red which only occurs in small quantities but is, nevertheless, the more valuable of the two. The separation of the two colouring matters is thus effected. The florets are macerated with water which extracts the yellow colouring matter. When the maceration is complete and yellow colouring matter is no longer extracted, the florets are mixed with a dilute solution of carbonate of soda (*sajji matti*) which extracts the pink colouring matter. The cotton is worked in this solution in the cold for a short time. The bath is then acidulated with tartaric acid and the cotton worked in it for a short while whereby the pink colour makes its appearance. Native dyers use lemon juice for acidulating. The action is similar to that of tartaric acid. Silk may be dyed similarly but safflower is not suited to dyeing wool.

Although the yellow colouring matter in safflower is generally regarded as useless, Hubner has shown that certain mummy cloths which he examined had been dyed with safflower yellow (vide *Journal of the Manchester School of Technology*, Vol. 3, page 359). He found that these cloths contained appreciable amounts of magnesium sulphate, and his experiments proved that an addition of magnesium sulphate helped cotton previously mordanted with iron to take up the yellow dye pretty well and the shades obtained were similar to those of the mummy cloths. The Egyptians were therefore acquainted with the right way of using safflower yellow.

Strange as it may appear, safflower yellow does not dye cotton in conjunction with aluminium and tin mordants.

Wool, however, possesses affinity for the yellow colour and may be dyed direct.

(9) MAJITH. (*Rubia cordifolia*).

The root and twigs of this plant contain a dye-stuff identical with madder. *Majith* was largely used in this country before the advent of synthetic alizarine. Its cultivation has now, it seems, entirely gone out. It is at present greatly in demand all over India, but enquiries made so far have shown that it cannot be had in quantities large enough to meet the demand for it. It is undoubtedly one of the most valuable indigenous dye-stuffs. With its help red, maroon, and bordeaux shades of excellent fastness to light can be dyed on all fibres. It is the basis of a great many colours required by the calico-printers. The Farrukhabad calico-printers were at one time large users of this dye-stuff and would be glad to go back to it if supplies were forthcoming. *Majith*, as might be expected, dyes very fast shades on both wool and cotton. The best results on cotton are obtained by using the Turkey Red process.

(10) CUTCH OR KATHA. (*Acacia catechu*).

The catechu tree is found in several parts of India. An extract made by boiling the wood in water is still largely used in dyeing. Catechu is exported to Europe for use in dyeing and tanning. Catechu may be applied to all fibres, though it is most largely used for dyeing cotton. The usual method of dyeing cotton consists in boiling the goods with an extract of catechu with the addition of copper sulphate, the weight of the copper salt being 10 per cent. of the weight of the colouring matter. The goods are squeezed, allowed to stand for a short time, and then boiled in a fresh hot bath containing 2 per cent. bichromate of potash, washed and dried. Catechu brown is one of the fastest colours known.

(11) PATANG OR SAPPAN WOOD.—(*Cæsalpinia sappan*).

This tree is said to grow abundantly in Cuttack and in Central India. It is a variety of the so-called Brazil wood which was once upon a time very largely used in dyeing in Europe. The colouring principle, *brazilein*, exists in a colourless condition in the freshly cut wood and is by oxidation converted into the true colouring matter *brazilein*. The wood is similar in its composition to logwood. The oxidation of the colouring matter is carried out by a process of "ageing" in exactly the same way as logwood.

Patang is a valuable colour-yielding material. It can be used for producing brilliant shades of red, crimson, and purple and is very suitable for calico-printing.

(12) LAC DYE.

This substance is of animal origin. It is the product of a small insect called *Coccus lacca* which lives on the twigs of certain trees such as *peepul* and *ber*. The incrustation produced by these insects on the twigs of the trees consists of (1) resinous matter, (2) colouring matter. The colouring matter is dissolved out by means of water or a weak alkali, the resin being left behind. The latter on melting and straining through canvas cloth constitutes *shellac*. The colouring matter is precipitated from its solution by means of alum and is afterwards pressed into cakes and sent out either for export or for sale locally.

Lac dye is manufactured largely in these provinces, though like other natural products it has lost much of its former importance Lac dye is dyed on wool, chiefly on tin mordant. It yields beautiful scarlet and crimson shades.

(13) INDIGO.

A description of this is perhaps unnecessary here. Its use and importance are too well known to be drawn attention to in this paper.

CONCLUSION.

In the scope of this report it has been only possible to allude briefly to the dyeing values and properties of the various colouring matters examined. Exhaustive trials have already been made with all the above dye-stuffs in conjunction with various mordants on both wool and cotton. The dyeings obtained in each case have been tested for fastness to light, washing, and milling. All these samples are being shown at the Exhibition of German and Austrian Goods now open at the Upper India Chamber of Commerce, Cawnpore.

These samples have already attracted the attention of users of dye-stuffs who have visited the exhibition, and enquiries respecting them have been received from one or two places.

Surprising as it may appear at first sight, India's natural resources are capable of supplying dye-stuffs required for producing any colour.

The thirteen dye-stuffs described above will enable a clever dyer to produce almost any colour.

We have in the list dye-stuffs yielding yellows, olives, browns, khakis, slates, greys, blacks, reds, scarlets, pinks, and blues. Suitable combinations of these colours will give us almost any shade.

The fastness of many of these dye-stuffs is not so bad as one is often led to believe.

It must, however, be admitted that most of these dye-stuffs are not available to-day in large quantities and the prices are consequently prohibitive.

Haldi, *cutch*, safflower, lac dye, and indigo are commercial products and may be had in fairly large quantities. *Tun*, *tesu*, *arusa*, and *Tephrosia* occur wild and arrangements may easily be made for collecting them. *Harsinghar* and *naspal* are not exactly wild products and so their collection will necessitate special arrangements being made.

Majith and sappanwood are perhaps the most difficult to get at and so far as we have been able to gather their cultivation has practically gone out, but an enquiry into the matter is still proceeding.

A systematic study of the properties and methods of application of these dye-stuffs would no doubt bring to light many valuable facts which would make the dye-stuffs more popular with the dyer.

There is every likelihood of a great many more colouring matters being found in the forests of India but this would be a matter for the Forest Department to deal with.

II

The examination of indigenous dye materials has been continued in the Technical Laboratory at Cawnpore. A communication on this subject has already been made to Government. Since then some additional dye materials have been examined and the following is a brief account of their properties and methods of application in dyeing.

(1) KACHNAR—(*Bauhinia racemosa*).

This is a shrub very common in these provinces. The bark yields a red dye which is largely associated with tannin. The dye is not very bright but nevertheless it may be employed for dyeing dull reds on cotton. It may be dyed on cotton without the help of any mordant. Cotton seems to have an affinity for it. Faster results are obtained on alumina or tin mordant. *Kachnar* bark is said to be used in Burma for obtaining a dull black colour on cotton. For this purpose the cotton is dyed direct in an infusion of the bark and is then worked in mud whereby the dull red colour is changed into a black (*vide* note by the Conservator of Forests, Eastern Circle, Burma, 1896). The bark can be had in any quantity, and may be of service to tent manufacturers who require a dull red colour for the inside of tents.

(2) PEEPUL—(*Ficus religiosa*).

The roots of this well-known plant were examined and found to contain a red dye which gives a good pink on cotton mordanted with alumina. The shade so obtained is fairly fast.

(3) RED SANDERSWOOD—(*Pterocarpus santalinus*).

This is a small tree occurring in Southern India. The wood yields a valuable red dye. It was largely used in dyeing before the advent of synthetic colours. The dye principle is called santalin. It was prepared in the laboratory in an impure state from an ethereal infusion of the wood. The crystals deposited from the ethereal solution were further purified by washing them well with water, redissolving in alcohol, and precipitating with lead acetate. The precipitate was well washed with boiling alcohol and decomposed with sulphuric acid in the presence of alcohol, on removing the lead sulphate and concentrating the solution pure crystals of santalin were obtained. They melted at 103-105°C. (un-corr.)

Sanderswood dyes wool without any mordant. Very good shades of satisfactory fastness are obtained on cotton on tin and alumina mordants. The dye does not dissolve in water though it is freely soluble in alcohol, ether, and acetic acid.

(4) ROLI OR KAMELA POWDER—(*Mallotus philippinensis*).

This dye is obtained from a small tree found along the foot of the Himalayas and in Southern India. The fruits have red glands on the surface of the capsule and the powder is obtained by crushing or breaking up these glands. Kamela used to be largely employed for dyeing silk. It gives a beautiful yellow on silk mordanted with alumina. The shade obtained compares favourably with that dyed with chrysophenine. The dyeing must be done in an alkaline bath.

(5) AKHROT—(*Juglans regia*).

The bark yields a valuable brown dye. It is of special importance for wool at the present moment because it yields on this fibre a fast shade which may easily be modified to a khaki. A great many dye trials were made and as a result of these the following conclusions were arrived at :—

(*a*) The deepest shade is obtained by dyeing with an addition of 3 per cent. acetic acid to the dye-bath. The fastness to light is, however, poor in this case.

(*b*) Fairly full shades were obtained on chrome-oxalic acid mordant or by the after chroming process. Both these give dyeings of excellent fastness to light and milling. The poorest results both as regards depth of shade and fastness to light and milling were obtained when the dyeing was carried out with an addition of 15 per cent. Glauber's salt to the dye-bath.

(6) KATHAL. (*Artocarpus integrifolia*).

The wood yields a yellow dye which may be dyed on cotton on alumina mordant. The shades obtained are good and fast.

(7) BARBERRY. (*Raswat*).

The bark, roots, and stem of this plant are rich in a very good yellow dye. This plant is plentiful in the Kumaun Hills. The aqueous infusion of the bark and stem is used as a medicine for ophthalmia and is highly prized as such. The dye principle of barberry is berberine which is an alkaloid containing nitrogen. Berberine was prepared in a state of purity from barberry by adding alcohol to the aqueous extract whereby all foreign matter was precipitated. On concentrating the filtrate crystals of barberine were obtained which were purified by recrystallisation from water.

Raswat is used chiefly as a dye for silk. It was dyed on cotton mordanted with alumina but dull shades were obtained. This was perhaps due to the presence of chlorophyl in the preparation which came from Naini Tal.

(8) *Rhus cotinus.*

The wood of this plant yields a dye similar to young Fustic. On cotton mordanted with alumina an orange yellow colour was obtained ; with tin an orange red was obtained. The dyeings are, however, not fast to alkalis and soap.

THE AQUATIC WEEDS OF THE GODAVARI AND PRAVARA CANALS OF THE BOMBAY PRESIDENCY—A PROBLEM IN APPLIED ECOLOGY.

BY

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In 1915 the author was invited to examine and report on the weed growth in the Godavari and Pravara Canals of the Bombay Presidency, since this growth had in some places become so great as seriously to impede the flow of the water. The Godavari canals were accordingly examined from their pick-up weir at Madmeshwar lake to mile 31 on the Left Bank Canal and mile 49 on the Right Bank Canal. Similarly the Pravara Right Bank Canal was examined from its head-works for 18 miles. The Pravara Left Bank Canal, being still under construction, was not examined.

The weeds discovered were the following :—

(1) *Potamogeton perfoliatus*, Linn.
(2) *Potamogeton pectinatus*, Linn.
(3) *Vallisneria spiralis*, Linn.
(4) *Hydrilla verticillata*, Casp.
(5) *Naias* (?) species.
(6) An alga, resembling *Oedogonium.*

With the exception of the alga, the weeds mentioned are plants rooted in the soil, with their shoots rising into the water to various heights. *Potamogeton perfoliatus* (Plate VI), is the most serious pest, and the impeding of the flow in the canals is due to it. This plant has a creeping rhizome, two to four inches below ground, from the nodes of which slender adventitious roots penetrate deeper into the

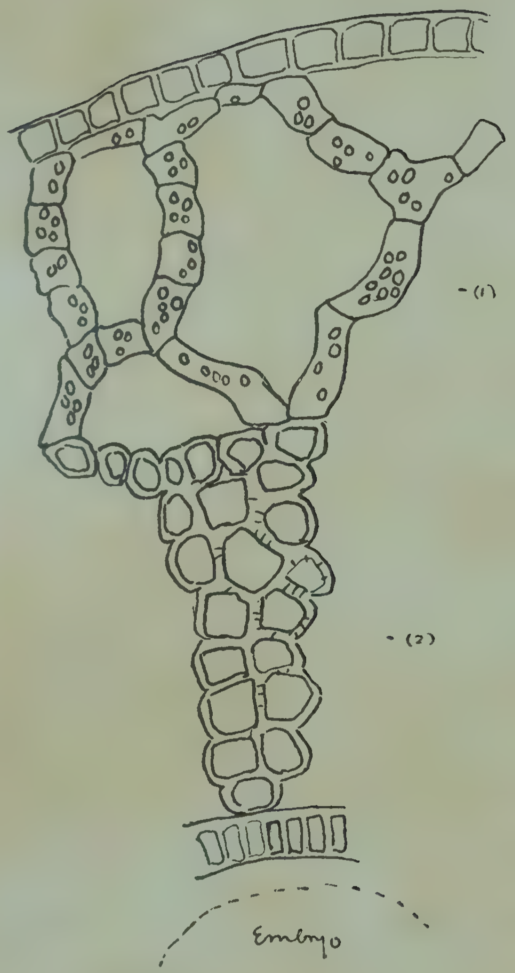


Fig. 1.

Transverse Section of Fruit coat of *Potamogeton perfoliatus*, showing
(1) starch containing floating tissue, and
(2) protective sclerenchymatous sheath.
× 124.
Semi-diagrammatic.)

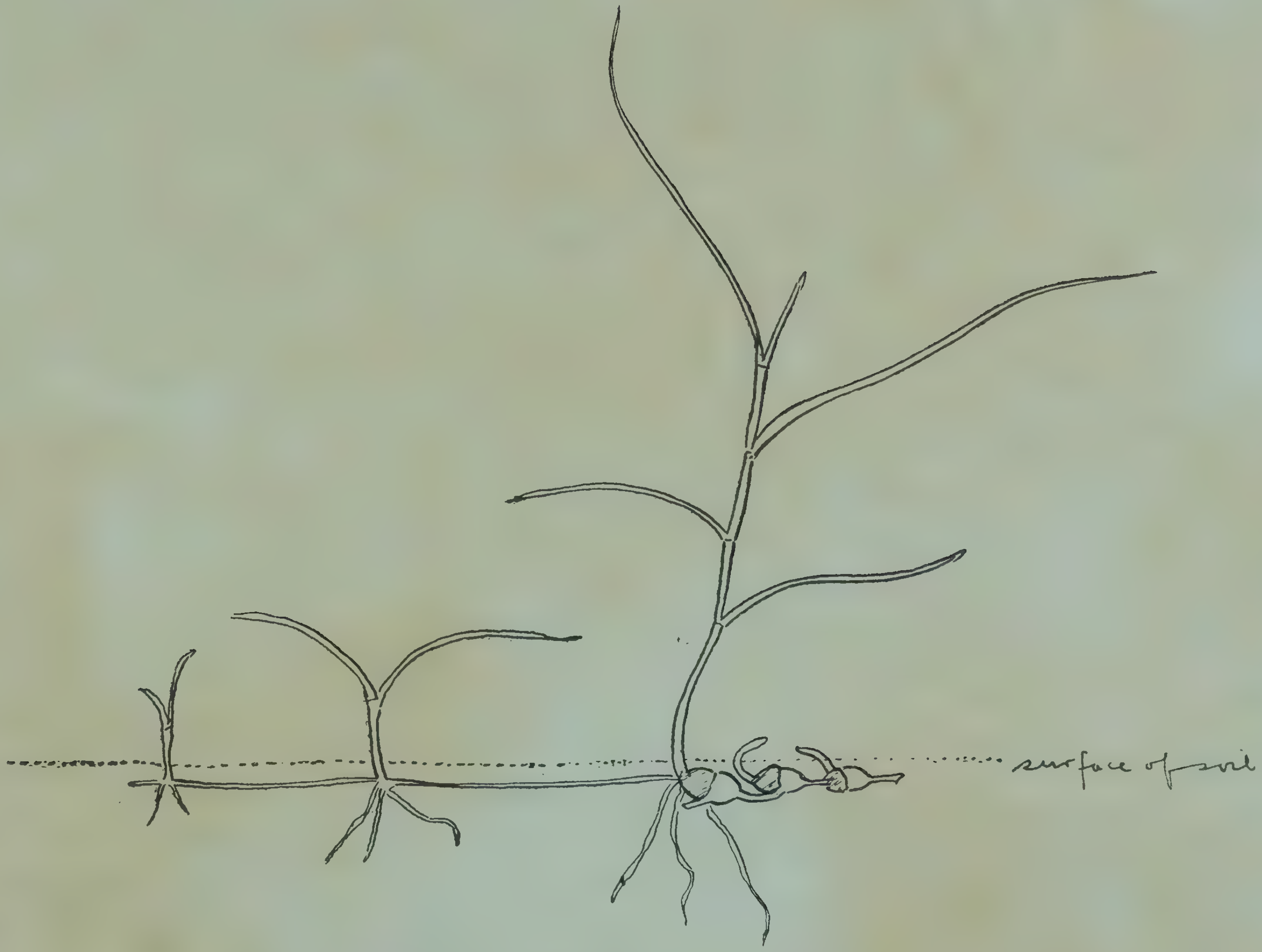
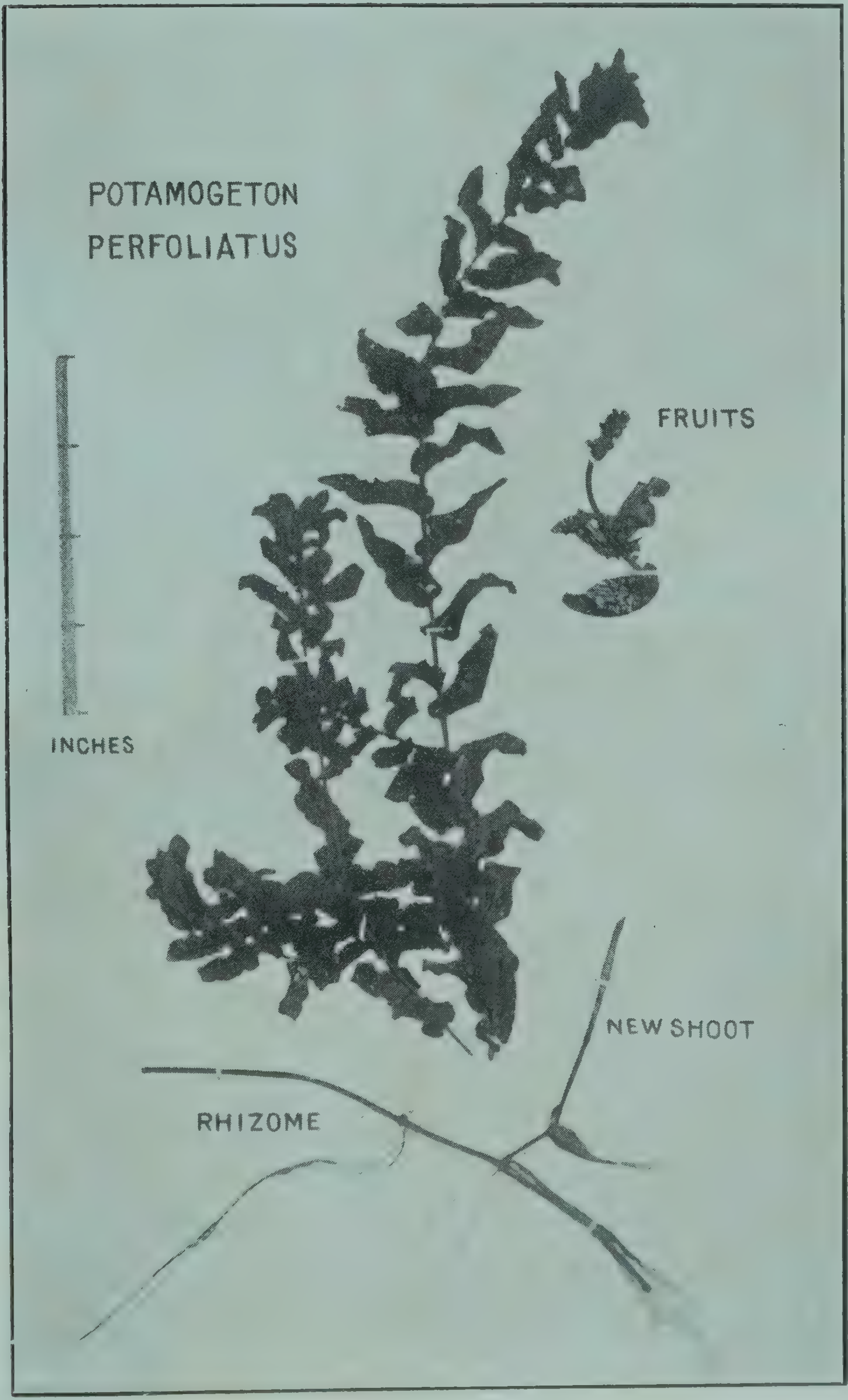


Fig. 2.

Plant of *Potamogeton pectinatus* 17 days after germination of resting tuber ; two ungerminated tubers attached. Natural size.

(Semi-diagrammatic.)



Potamogeton perfoliatus.

soil. The growth of this rhizome appears to be monopodial. The stems arising from its nodes may be of great length. One taken at random from Madmeshwar lake measured 12½ feet from root to tip, the branches and leaves being confined to the top 2 feet. In the 49th mile of the Godavari Right Bank Canal, in water 10 feet deep, two stems taken at random measured 12 and 10 feet respectively with branches and leaves on the terminal 1½ feet. It is unnecessary to give a detailed botanical description of the plant, but points of ecological interest must be considered. Among these, the reproduction of the plant is of the first importance. As already mentioned, the creeping stem forces its way through the soil, sending up new above-ground stems. Reproduction by fruits appears to take place freely. In the Madmeshwar lake many plants of *P. perfoliatus* were in flower or fruit. The small compact spikes stand about one inch above the water. The method[1] of pollination is by wind, and judging from the copious formation of fruits, conditions are favourable. Some of the fruits fall off from the spike and float for a time, and it may be that the whole spike also becomes detached, but this has not yet been observed by the writer. The fruits are 1 mm. × ·2 mm. × 2 mm., ovate and pointed in shape, and very thick coated. Fig. 1 shows a cross section of such a fruit with floating and protective tissues. The length of time that these fruits float and the factors affecting it have not yet been determined. This point is important, especially in the present case, where the regulators of the pick-up weir are so arranged as to draw off the surface water only.

It is probable that the Godavari canals have been infected from the Madmeshwar lake by the drifting down of these floating fruits. Leaving this point for the moment let us see if there is any discoverable reason for the extraordinary prevalence of *Potamogeton perfoliatus* in the said lake. The weir which is the cause of the formation of the lake was completed a few years ago. After its completion, a considerable area of previously dry land was submerged and one village had to be vacated. In the first year after the completion of the weir no weeds were observed in the lake. The exact date of their appearance is doubtful. It is possible that fruits of *Potamogeton perfoliatus* from plants in higher pools of the Godavari drifted down into the lake. The newly submerged land would be, as far as aquatic plants were concerned, *a denuded area*, and invasion would be easy. It is interesting to note that the portions of the lake occupied by weeds correspond roughly to the recently submerged areas, while the beds of the Godavari and Kadwa rivers, running through the lake, are clear of weeds. At the same time there are clear patches of water close to weedy areas which cannot be thus easily accounted for. It may be that at such points the substratum is not suitable for the growth of the rhizome.

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[1] Knuth, *Handbook of Flower Pollination* (Answorth Davies), vol. III, p. 507.

The freedom of the river beds from weeds is probably due to the greater depth, and possibly to the greater opacity of the water. The influence of the Godavari is felt more in the Right Bank Canal and, if the water reaching that canal is coming unusually directly from the river channel, then the water is more muddy and at the same time more free of floating fruits of *P. perfoliatus*. Such a direct flow appears to have occurred in 1915, weed growth in the Right Bank Canal having been considerably retarded during September and October, although other conditions appeared normal.

The weed grows in water from 1 foot to 20 feet deep. This latter figure is not the maximum depth at which it can grow, but is merely a deep sounding taken casually in a weed area in the Madmeshwar lake. Scott Elliot[1] reports *Potamogeton* at 26 feet in Bruyant, France.

Variations of turbidity or velocity of water seem to have little effect on the distribution of the weed. The leaves occurring on the last 2 feet of the stem are always just below the surface and hence get plenty of light even if the water be muddy. The weed was found in water of all velocities from zero to 4 feet per second and thrives equally well in them all.

It is a curious circumstance that the weed occurred also here and there in borrow-pits beside the canal but having no direct connection therewith. There are three possible explanations of the infection of these borrow pits. The fruits may have been carried (1) on the feet and feathers or in the stomachs of aquatic birds, or (2) in mud on the feet of cattle, or (3) they may have come from bunches of the weed piled on the banks at the time of cleaning of the canals. The fruits may then have been washed or blown down into the pits.

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[1] Scott Elliot, *Modern Botany* (1910), p. 132.

Complete closure of the canal for a prolonged period would doubtless kill the weed, but there is so much land under perennial irrigation from the canal that a prolonged closure is impossible. A closure which is sufficient to kill the exposed stems does not affect the under-ground rhizomes, which begin growth when water is once again let down the canal.

The vegetative growth of the weed is considerable from November to February and is at its maximum during December and January, just after its fruiting period in November. During the hot weather the vegetative growth diminishes, and is more or less dormant during the rains. In this respect, this aquatic weed forms a remarkable contrast to most of the land vegetation of its neighbourhood.

It is possible that the fall in temperature during the rains is the factor that checks weed growth. The factor of extra silt and consequently greater opacity of the water must also be taken into account. Only experimental evidence, however, can determine which of these factors is the more important.

Any methods for controlling this weed must, as far as these observations go, aim at (1) the prevention of fruit formation in the Madmeshwar lake so as to avoid further infection of the canals; (2) the repeated cutting or dredging by suitable apparatus of the weed in the lake to prevent its further spread therein; (3) the extirpation of the rhizomes of the plants now established in the canal. Means to attain these three ends are being considered.

Of the other weeds, *Hydrilla*, *Naias* (?) and *Vallisneria* were found in Madmeshwar lake completely submerged and out of sight in 4 feet of water. None of them were in fruit. They occurred at various points in the canals but were not serious pests.

Potamogeton pectinatus was found in flower at three points in the canal. It was found also in the lake. On account of its linear leaves, it does not hold up the water in the same way as *Potamogeton perfoliatus*. *Potamogeton pectinatus* has peculiar vegetative reproductive bodies not mentioned by Hooker, Cooke, or Woodrow, but briefly referred to by Continental writers.[1] These bodies are small rhizomes consisting of closely packed tubers; each tuber having on one side a shoot ready to start into growth, and on the other a slender internode connecting it with the next tuber. Small chains of these tubers were found both floating in the water and buried in the soil of the canal. The author was absolutely ignorant of their relationships until he grew one experimentally and got from it an unmistakable plant of *Potamogeton pectinatus*. Fig. 2 on p. 66 shows the plant produced. The germinating of such resting-bodies at this season tallies with the cycle of growth already noticed in which the monsoon is the resting season for such aquatic plants.

In the Pravara Right Bank Canal the weeds were much fewer, and the head-works, which is comparatively small, showed only one specimen of *Potamogeton pectinatus* and no *Potamogeton perfoliatus*. The latter is, however, found in the canal and the infecting fruits doubtless come from higher up the river.

The whole question of the control of the weeds of these canals constitutes a most interesting problem in applied ecology.

ADDENDUM.

Since the above paper was written for the Indian Science Congress, further collection of weeds from the Madmeshwar lake, and observation of specimens grown in tubs have brought to light the fact that the floating stems have the power of producing rooted branches adventitiously. It is likely that these branches later on fall off or are detached by the decay of the parent branch. This discovery makes the task of eradication of the weeds even more difficult since it will be necessary not only to prevent fruit formation, but to check the drifting down of these rooted and detached branches.

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[1] Engler and Prantl, Natürlichen Pflanzenfamilien II Teil, I Abteiling p. 195 Handwörterbuch der naturwissenschaften, X Band, 519.

Fruits sown under water in November 1915, germinated in March 1916.

The artificial conditions in the tubs induced flowering after four months.

It appears also that there are probably three varieties of *Potamogeton perfoliatus* in the lake. Specimens of these are now being grown to determine if they are genetically distinct.

IRRITABILITY OF THE BLADDERS IN UTRICULARIA.

BY

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A SPECIES of *Utricularia* very near *flexuosa* is a free floating insectivorous plant (found in a tank in Madras). The leaves are finely dissected. The bladders that entrap insects hang by short stalks from the axes of the leaves (Plate VII, fig. 1). They are oval in shape and are broader in one direction than the other. The mouth of the bladder is horse-shoe shaped, with the bend of the horse-shoe posterior and the base anterior. The mouth is surrounded by a ridge which is produced at the two ends of the base of the horse-shoe into two stout projections from which branched hairs start. These hairs are referred to by Darwin as the antennæ. Except along the base of the horse-shoe the ridge is fringed with long pointed hairs (Plate VII, fig. 2, and Plate VIII, fig. 1).

The valve or trap-door of the bladder is attached to the inner and lower margin of the ridge all along the base of the horse-shoe and to a very short extent along the sides. In the living condition the valve is not flat as is commonly supposed but is transversely convex and dome-shaped when looked from above. The apex of the dome lies very near the bend of the horse-shoe so that the curve of the arch rises very gradually from the base up to very near the bend of the horse-shoe and then has a sharp fall (Plate VIII, fig. 2). From the apex of the dome start six or eight long pointed hairs arranged in two sets with a short space between. The hairs stretch towards the base projecting slightly upward and are nearly as long as the

PLATE VII

Fig. 1. *Utricularia* Sp., very near *U. flexuosa.*

Fig. 2. Single bladder enlarged. Horse-shoe shaped ridge or "collar" round the mouth, produced into two branched hairs called the "antennæ" and surrounded with simple hairs. The shaded portion on the valve near the base of the horse-shoe shows the position of a large number of secretory hairs. The six irritable hairs on the valve are seen pointing towards the antennæ.

PLATE V

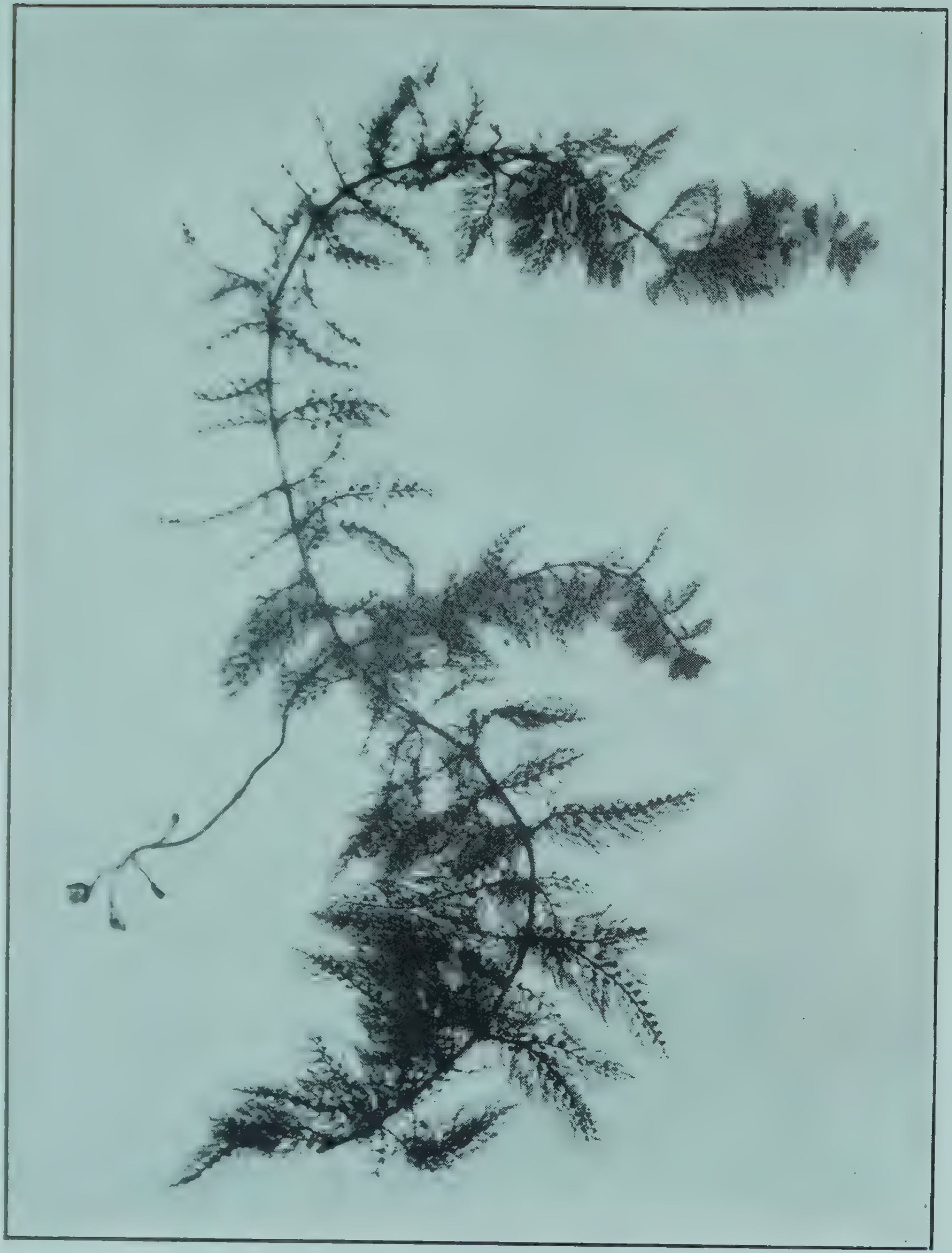


Fig. 1.

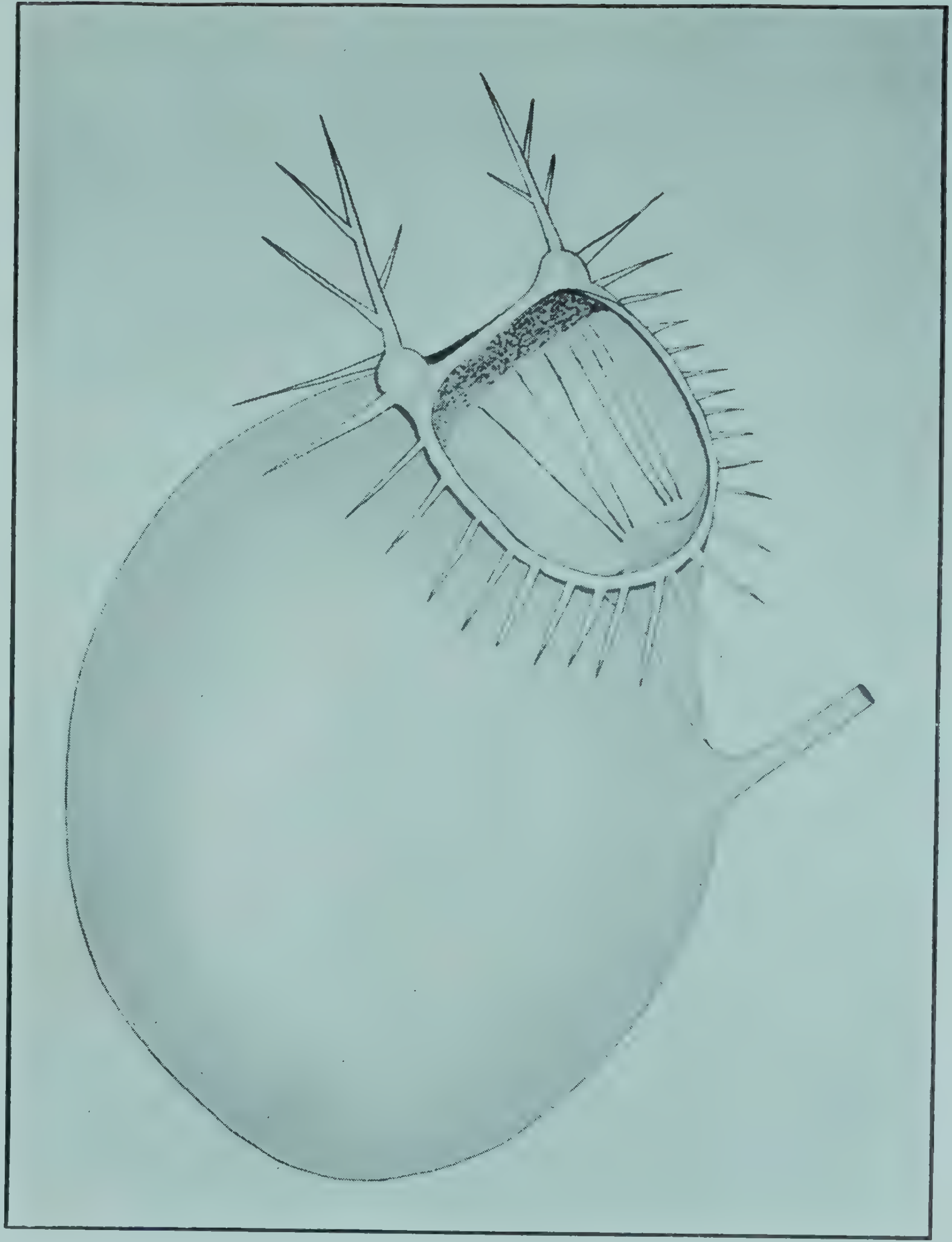


Fig. 2.

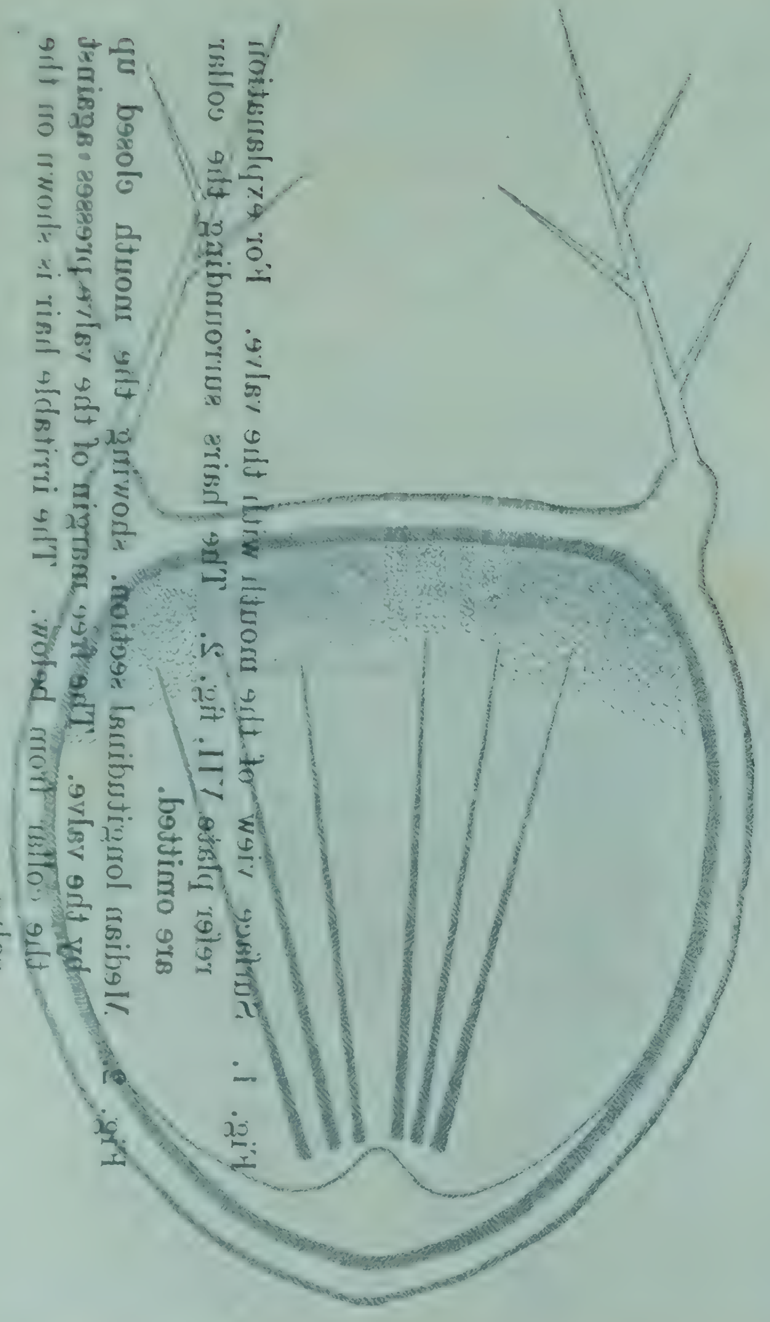


Fig. 1

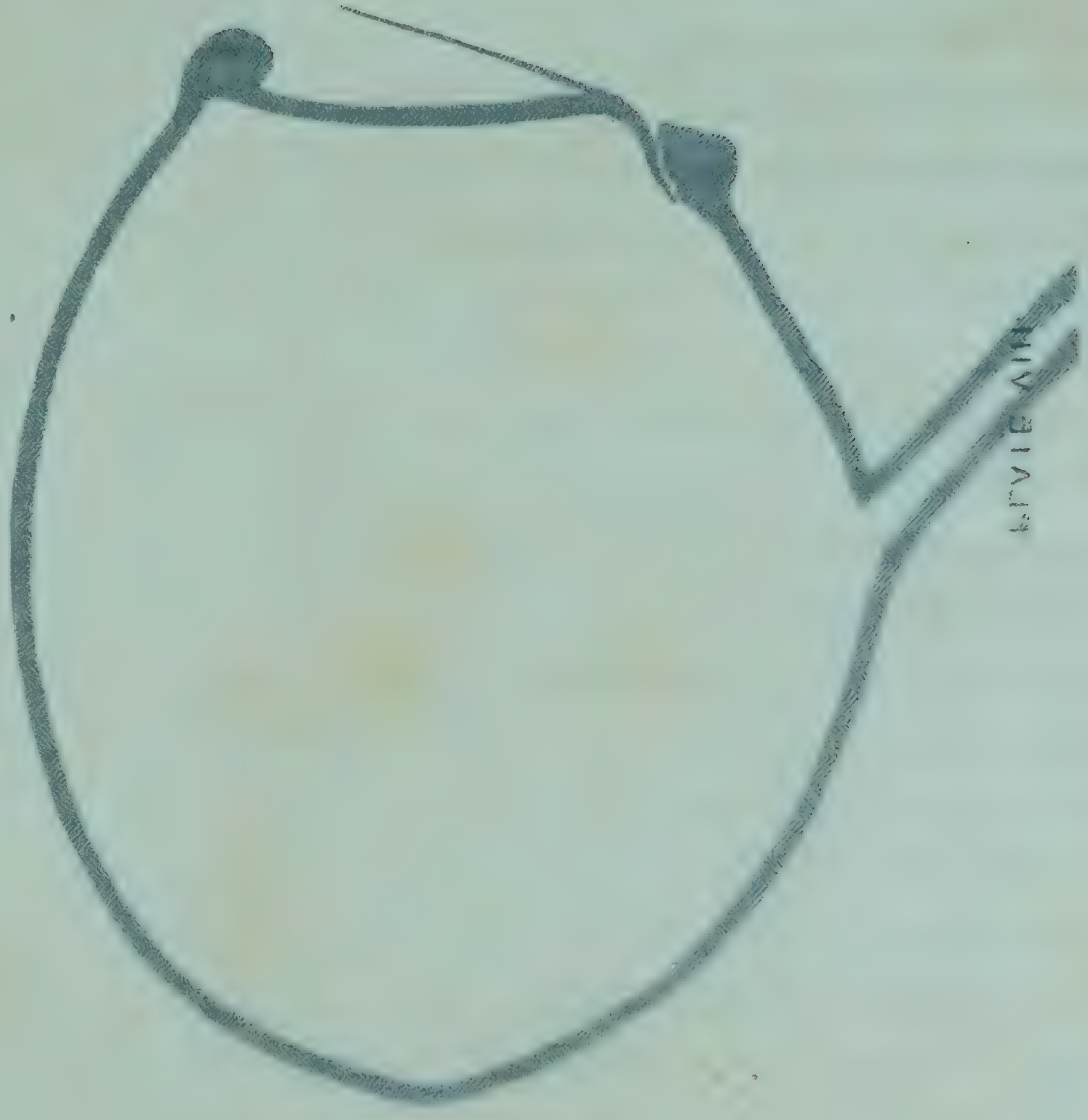


Fig. 2

PLATE VIII.

Fig. 1. Surface view of the mouth with the valve. For explanation refer plate VII, fig. 2. The hairs surrounding the collar are omitted.

Fig. 2. Median longitudinal section, showing the mouth closed up by the valve. The free margin of the valve presses against the collar from below. The irritable hair is shown on the valve.

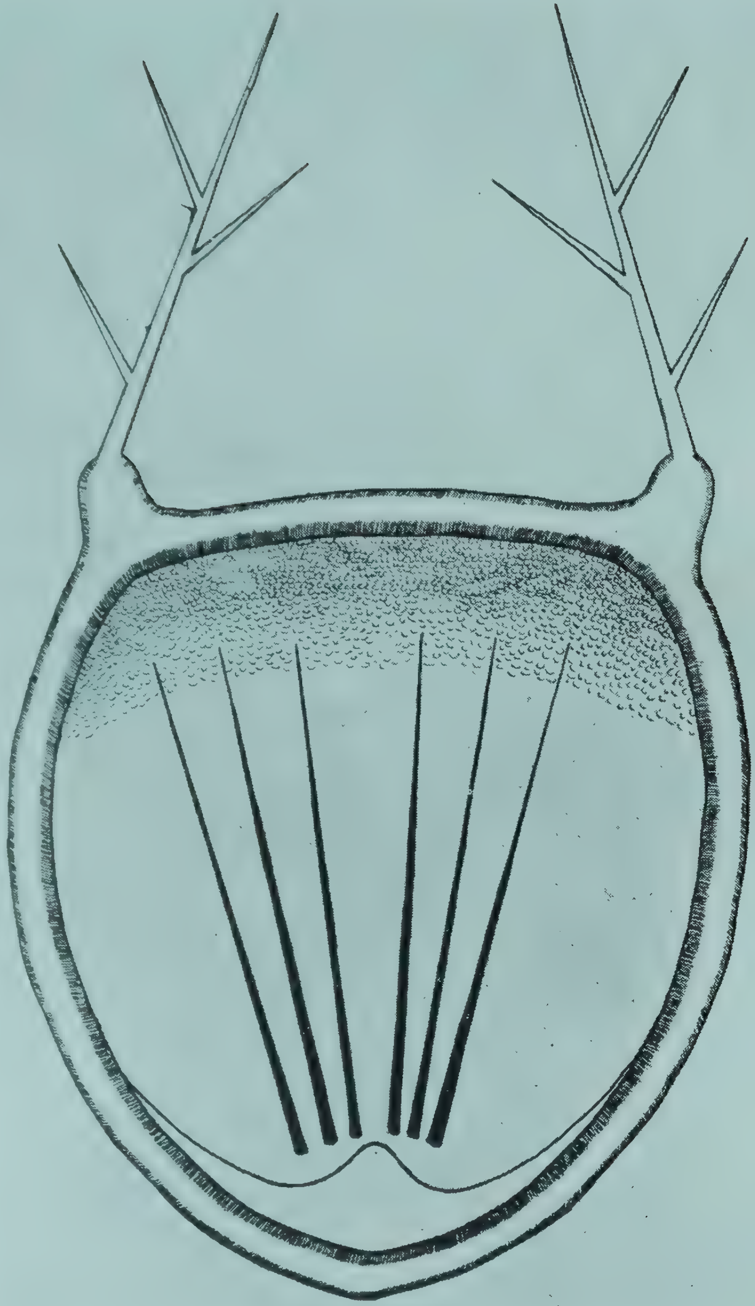


Fig. 1.

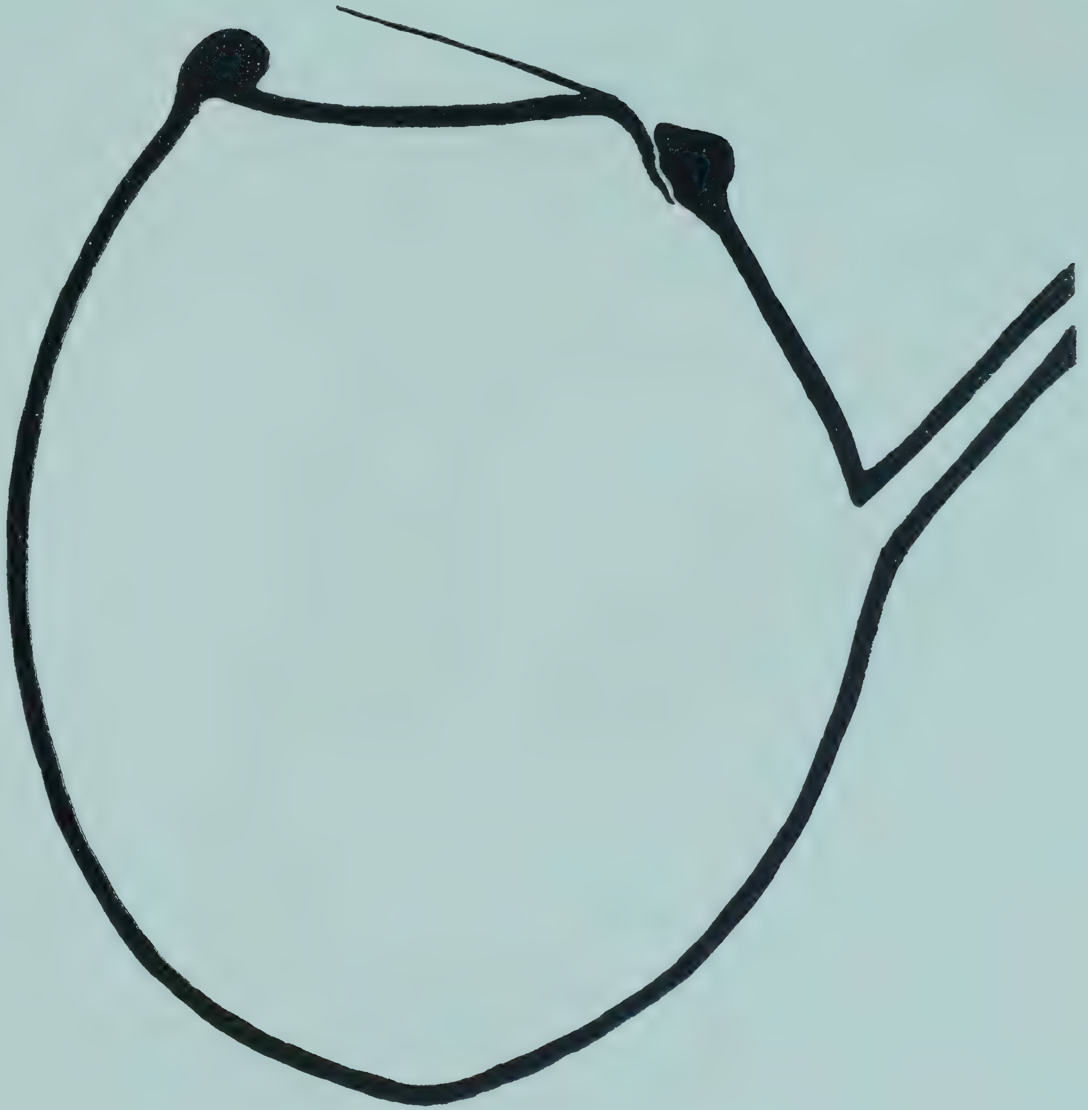


Fig. 2.

valve. The portion of the upper surface of the valve nearest the base of the mouth is densely clothed with club-shaped hairs which are glandular and secretory. The valve has a thin margin which goes below the ridge of the mouth all round and is tightly pressed against it.

Darwin has shown that small crustaceans and other animalculæ are found inside these bladders and that, since they cannot escape once they are caught, they die and decay. The decayed animal matter is absorbed by peculiar quadrifid hairs, found on the inner surfaces of the walls of the bladders.

My attention was drawn to a peculiar behaviour of this plant, when I was distributing specimens to my class for studying the structure of the bladders. As the specimens were lifted out of water to be placed in smaller dishes, they made light crackling sounds resembling the ticks of a watch. The sounds were unaccountable by anything I knew of the structure of the different parts of the plant. After a series of observations, they were located as coming from the bladders. The state of the bladders before and after lifting the plants out of water, gave the clue. When the plants had been allowed to remain quiet for two or three days in water, among the full grown bladders nearly 25 per cent. were found to be half filled with air and half with water. Nearly 50 per cent. were found to be completely filled with water and in some of these, the small organisms entrapped may be seen. The rest were nearly empty, with the walls closely adpressed against each other, so that there was very little cavity inside, and the bladder as a whole was biconcave.

The first two kinds of bladders with the walls convex and with the cavity inside filled with water or water and air, I will designate as "full." The last with its walls concave and with very little cavity, I will call "hungry." In every case the valve or trap-door was tightly pressed up against the rim of the mouth. When the plants were lifted up and replaced in water, there were very few hungry bladders left and in their places were now found some completely filled with water and others with water and air. There was no change in the full bladders. From this it was inferred that the hungry bladders, when they were disturbed and came in contact probably with the leaf segments or other parts of the plant, opened out and let in water or water and air. Hence I suspected that the bladders were irritable and that the valve was very likely not simply a passive elastic door to be pushed in as Darwin supposed by an unwary or inquisitive animalcule, but an active trap-door which helped the bladder to forcibly suck in its prey.

As to the manner by which the animalcules make their way into the bladders, Darwin says " Animals enter the bladder by bending inwards the posterior free edge of the valve which from being highly elastic shuts again instantly. As the edge is extremely thin and fits closely against the edge of the collar, it would evidently be very difficult for the animal to get out when once imprisoned and apparently they never do escape. As I felt much difficulty in understanding how such minute and weak animals as are often captured, could force their way into the bladders, I tried many experiments to ascertain how this was effected. The free margin of the valve bends so easily that no resistance is felt when a needle or thin bristle is inserted. A thin human hair fixed to a handle and cut off so as to project barely $\frac{1}{4}$ of an inch entered with some difficulty, a longer piece yielded. On three occasions, minute particles of blue glass (so as to be easily distinguished) were placed on valves while under water and on trying gently to move them with a needle, they disappeared so suddenly, that not seeing what had happened, I thought I had flirted them off ; but on examining the bladders they were found safely enclosed. The same thing occurred to my son who placed little cubes of green boxwood on some walls and thrice in the act of placing them on or whilst gently moving them to another spot, the valve suddenly opened and they were engulfed. He then placed similar bits of wood on other valves and moved them about for some time and they did not enter." " To ascertain whether the valves were endowed with irritability, the surfaces of several were scratched with a needle or brushed with a fine camel-hair brush so as to imitate the crawling movements of small crustaceans, but the valve did not open. We may, therefore, conclude that the animals enter merely by forcing their way through the slit-like orifice, their heads serving as a wedge." "But," says Darwin, "I am surprised that such small weak animals should be strong enough to act in this manner, seeing that it was difficult to push in one end of a bit of hair $\frac{1}{4}$ of an inch long." Darwin evidently came to the above conclusion quite half-heartedly and he missed the correct solution by a hair's breadth.

I will first corroborate Darwin's idea that it is unlikely that such small and weak animals should be strong enough to enter the bladders by pushing in the valve, and then try to explain the mystery of the particles of blue glass and boxwood. I tried to get an idea of the pressure the valve was able to withstand before it yielded and was pushed in. For this purpose, I used a spring which was fixed to a stand by one end. To its other end a piece of cork, with a small metal cup on its top and a needle stuck in at the bottom, was attached, so that the blunt end of the needle hung free. Below this was placed a Ziess's hand microtome which has a flat circular top, with a hole in the centre, through which the block-holder can be moved up and down by a micrometer screw. A bladder was cut across and the upper half, with the valve, was made to rest on its cut end, inside a narrow glass ring fixed to a slide. The ring was filled with water so that the cut bladder was immersed in water. The slide was placed on the microtome and slowly raised until the free end of the needle rested on the valve just touching it. Care was taken to see that the end of the needle did not come in contact with the ridge surrounding the mouth. The orifice was big enough to admit the end of the needle freely. Sand grains were now added to the metal cup until the lid just gave way. The weight of the sand grains which was 270 mg. gave an approximate idea of the pressure that the lid was able to withstand. This is likely not accurate, as here, the weight of the sand grains included not only the upward pressure of the valve, but also the weight necessary for the extension of the spring. To avoid it, as I thought, the action of the spring was reversed in this manner. The weight necessary for stretching the spring to a known distance was first calculated and then in the stretched condition the needle was made to rest on the valve. Now the valve was gradually raised until it gave way. The distance to which the spring was raised to effect this, was made out and from it the weight supported by the valve was calculated. The weight thus got was 250 mg.

Now, let us consider the pressure the organisms can exert on the valve. Though it was not possible to get an accurate estimate, the following considerations, I expect, will give an approximate idea of the pushing force of the crustaceans and others, found inside the bladders. The force, that these organisms can exert, can be derived in three ways : firstly, their weight ; secondly, the momentum with which they dash against the valve ; and thirdly, the activity of their own muscles or any other structures corresponding to them.

The first factor, namely the weight, is quite negligible, since it will be greatly or fully counteracted by the buoyancy of water. As regards the second source, namely the momentum, the habit of these organisms, when they approach the bladders, is of great interest. I have spent a long time watching for the suction of the animals into the bladders. Whenever an animal approached a bladder, its quick motion was stopped and it went round as if it were brousing along in search of food and in no case was there an aimless or unwitting impact with the valve. Darwin says " It is difficult to conjecture what can attract so many creatures, animal and vegetable feeding crustaceans, worms, and various larvæ to enter the bladders. Perhaps small aquatic animals habitually enter very small crevices like that between the collar and the valve, in search of food or protection." My observations lead me to believe, though I am not yet in a position to prove definitely, that the attraction for these animals lies in the secretion of the clubheaded hairs found profusely near the base of the horse-shoe on the valve. Since the animals when they are near the bladder move about very slowly, the second source of energy is also not of any consequence. The third source, that of muscular power, is hard to get at and can only be guessed ; but a different consideration will, I think, put this source out of court. The distribution and direction of the long-pointed hairs round the ridge are such that entrance into the horse-shoe is easy only through an arch formed by the antennæ or the very long branched hairs at the base of the horse-shoe. Now if an animal enters through this arch, it will necessarily come against the sharp points of the hairs which stretch from the apex of the valve towards this entrance. So it appears impossible for the animal to get at the edge of the valve and push it in. The above considerations, I hope, show that the presence of the animals inside the bladders cannot be due to their pushing their way in.

To see whether the suspicion that the bladders were irritable had any basis, the following experiments were done. First I selected some of the "hungry" bladders and irritated with a needle the different parts of the ridge, round the mouth and the valve. When the hairs at the apex of the dome of the valve were irritated, the adpressed sides shot out suddenly with a sharp explosive sound and the bladder got filled with water or air. I repeated this over and over again, so as to assure myself that I did not really push the valve in, but only irritated the hairs, and in the case of every hungry bladder the same reaction followed. No reaction occurred when any other parts of the region were irritated, so that I was able to assure myself that these particular hairs were the irritable hairs. Then I wanted to see whether similar conditions obtained when an animal was caught inside the bladder. It was found impossible to manœuvre the organisms to the bladders and, though I observed for a long time, I was not able to see an organism actually sucked in. But the critical question, whether a bladder is capable of sucking in the organisms if they irritate the hairs on the valve, was settled by another means. Once a dead fly, more or less in a putrifying condition, was found floating on the water in one of the dishes. I took the front half of the fly at the tip of a needle and irritated the hairs of a hungry bladder with the head of the fly. To my joy, the whole object was immediately sucked in. This set at rest my doubts as regards the capacity of the bladders to suck the organisms in, as the biggest of the crustaceans found inside were not more than $\frac{1}{3}$ of the head of the fly in size.

I wish to draw attention to the fact that the above experiments were done with the hungry bladders only. The full bladders do not react to irritation. This explains the mystery of the disappearance of the particles of blue glass and boxwood in some cases and not in others. I take it that the bladders that swallowed the particles were ' hungry ' and those that did not were ' full.' The same fact also explains the negative results obtained by Darwin when he irritated the bladders, as nearly 75 per cent. of the bladders in a plant are in the ' full ' condition and the ' hungry ' bladders are generally very few. It may also be due to the fact that the reaction to irritation is extremely quick and easily escapes notice.

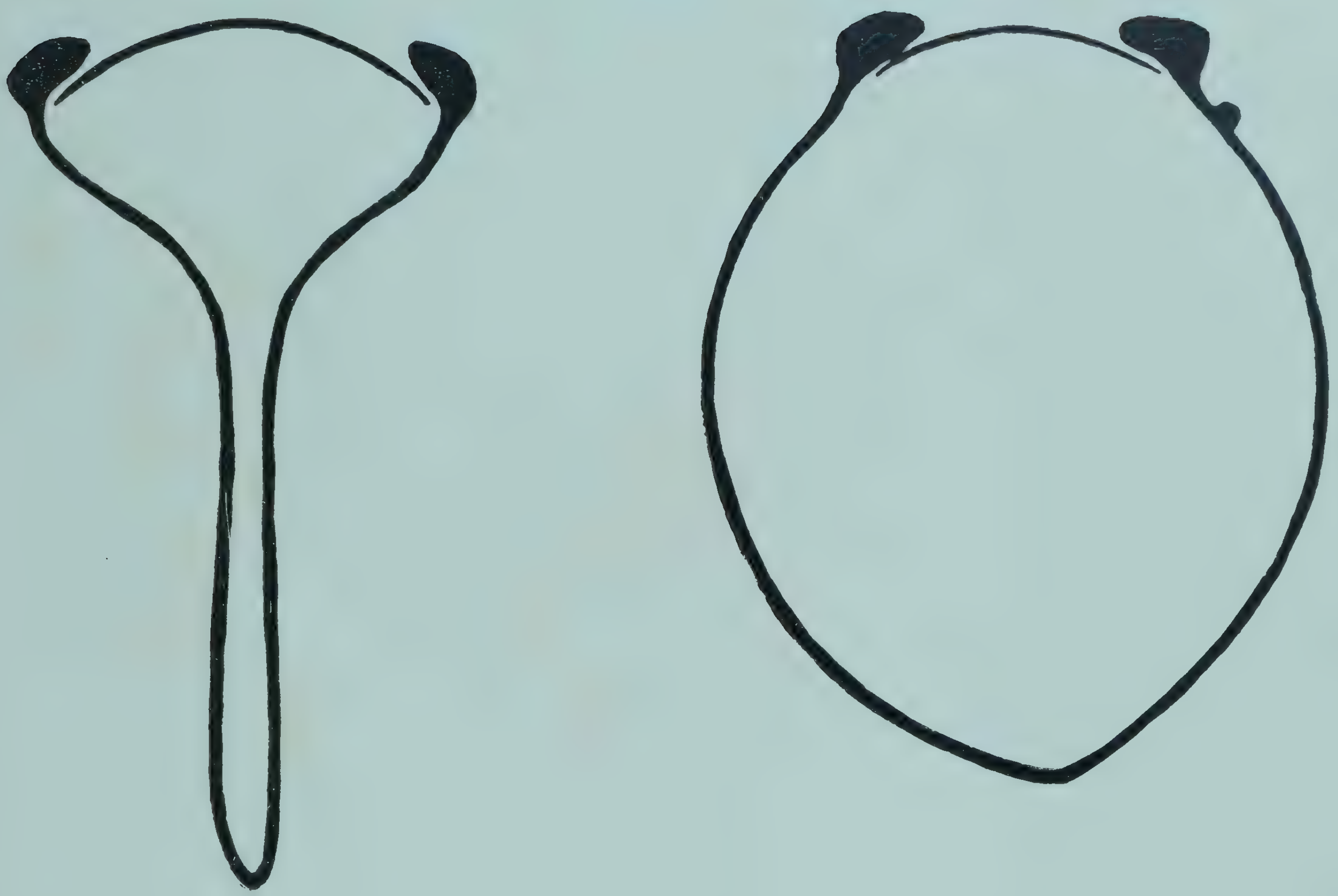
A few words about the mode of action under irritation. Owing to the quickness of reaction, it is impossible to observe directly the opening and closing of the valve. When the valve of a full or non-hungry bladder is pressed down with a needle as far as it could go, the irritable hairs project right in the centre of the opening. If an animal is sucked in when the valve is in this position, it should be either impaled on the hairs or the hairs should be broken. But I could never believe, that in such a delicate mechanism, this flaw could ever occur. The explanation was arrived at rather accidentally. In an idle mood I pressed out the contents of a full bladder with a pair of pincers. The contents came out through a slit formed by a portion of the margin of the valve being pushed out. When the pressure was relieved, the valve fell back quickly to its place and no water entered from outside ; but some air escaped from the intercellular spaces in the walls of the bladder and filled up the cavity. Then, I once again pressed out all the air and over again when more air came in. When the air was driven out twice or thrice, the bladder assumed the hungry condition. When I irritated the hairs, it reacted in the normal manner. I got very much interested and the whole operation was thrice repeated with the same bladder. The valve went in once again under irritation but never came back and the bladder was left wide open. When I looked through the open mouth, I could not see the irritable hairs and the passage was perfectly clear. It was then that the proper position of the irritable hairs, when reacting to irritation, was shown. On examination, it was found that the convex valve had become concave and boat-shaped, and the hairs were found safely

PLATE IX.

Fig. 1. Longitudinal section at right angles to the plane in plate II, fig. 2. The left-hand diagram shows the "hungry" condition with the walls concave and adpressed. The right-hand one shows the "full" condition with the walls convex.

Fig. 2. Median longitudinal section, showing the position of the valve when the bladder opens under irritation. The valve is concave and drawn back and has the irritable hairs laid in the hollow.

PLATE IX.



a Fig. 1 b

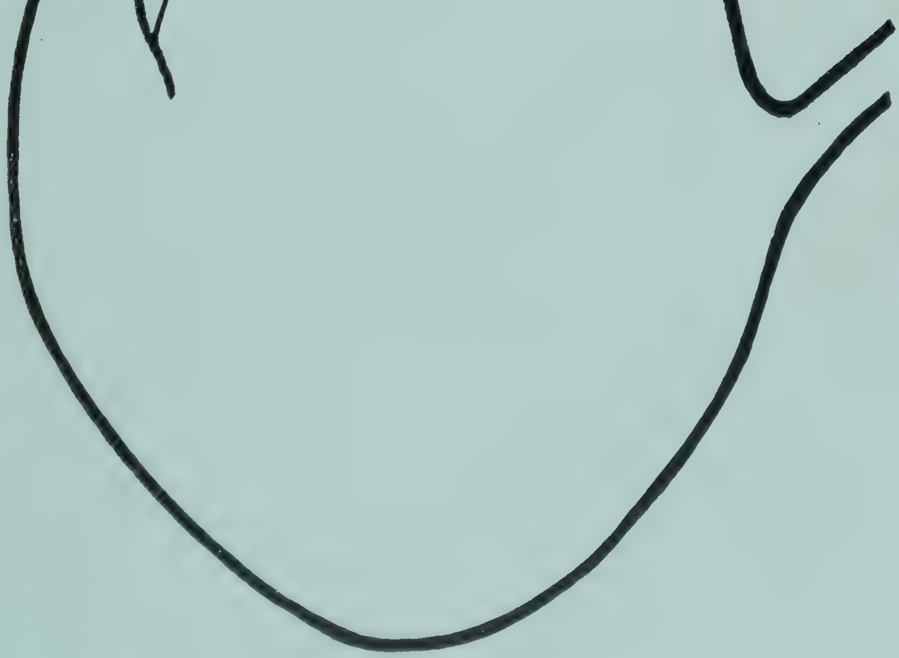


Fig. 2.

laid at the bottom of the boat. The orifice was fully open without any obstruction. (Plate IX, fig. 2.)

The nature and arrangement of the cells that go to make up the valve, the irritable hairs, and the ridge are very interesting. Their relation to the functions performed is under investigation.

MODELS TO ILLUSTRATE SEGREGATION AND COMBINATION OF MENDELIAN CHARACTERS.

BY

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It is not proposed in this paper to expound the principles of heredity discovered by Mendel. My object is merely to explain the working of models devised by me to demonstrate the behaviour of hereditary characters that conform with Mendel's principles, as they are transmitted from one generation to another.

I have taken glass beads to represent the determiners of hereditary unit characters. A coloured bead is used to represent the determiner of a dominant character. A colourless bead of the same shape and size is used to stand for the corresponding recessive, if the presence and absence hypothesis of dominant and recessive characters is to be illustrated. A certain modification of the entire model is devised to illustrate the working of the determiners of heredity, when the recessive ones are supposed to have a definite existence.

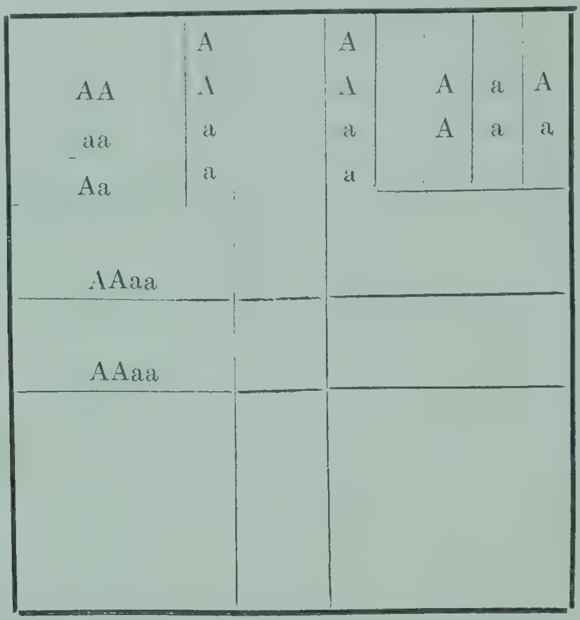
I have represented the idea of there being two determiners or a double dose of a dominant character in an individual by taking two coloured beads which are in every way identical. The single dose condition is represented by two beads of the shape and size but only one of them is coloured while the other is colourless. The nil dose or recessive condition is represented by two uncoloured beads. The use of any beads whatever to represent recessive determiners when they are conceived to have no existence at all is justified only on the score of convenience afforded in working the model.

The idea of indivisibility of the determiners and their segregation in the sexual cells involves the reduction in the sexual cells of a double dose when it is present in an organism to a single dose, and the formation of two sorts of sexual cells in equal numbers one carrying a single dose and the other a nil dose when the organism itself has got only one dose. This implies the existence of sexual cells of only two types with reference to a given determiner, one type carrying a single dose of it and the other none of it. Thus there are three types of organisms represented by the conventional symbols **A A**,**A a**, and **a a**, and called homozygous or pure dominant, heterozygous or hybrid dominant, and recessive which is always pure; but there are only two types of sexual cells, *viz.*, **A** and **a**. This fact is generally embodied in the doctrine of purity of gametes. Segregation is commonly spoken of in Mendelian literature, following Mendel's own conception of "pairs of differentiating characters and their mutual separation in the sexual cells" as "the dissociation of the allelomorphic or alternative characters in the constitution of the gametes," or symbolically the separation of A a from each other. The separation of A A and of **a a** (Mendel conceived of **a a** not as an absence but as a presence) also from each other was not noticed by Mendel, and has also apparently escaped the attention of most writers on Mendelism. The composition of different zygotes and of their gametes with reference to one character may be represented thus—

Zygotes	A A	A a	a a
Gametes	all A	A and a in equal numbers	all a

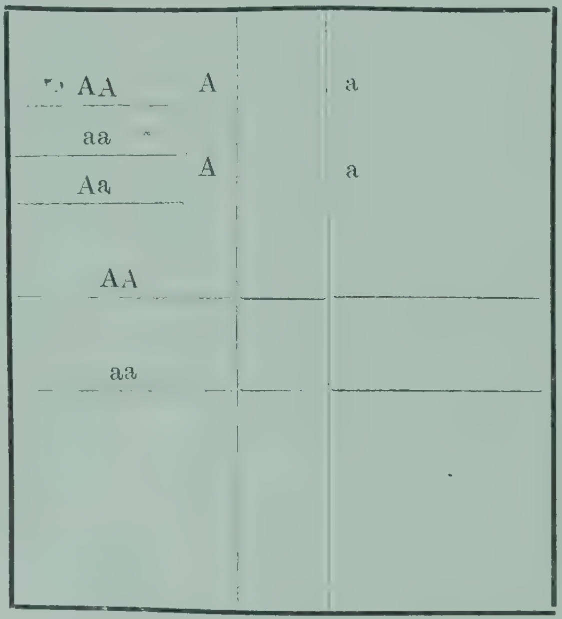
In my model which consists of a square frame work standing erect and carrying strings of beads the composition of the different types of organisms and of the gametes is shown by beads on different strings. The strings carrying the beads for gametes of one parent cross those of the other parent, and the composition of the resulting zygotes is shown by moving the beads to the points of intersection.

The following diagram which deals with the consideration of one character only will render clearer what I have just stated.



Note. The beads in the top left-hand square represent the zygotes and those in the top right-hand square the gametes produced by these zygotes.

It may be further simplified as given below which requires only fourteen beads in all.



When two characters are considered conjointly there would be nine (3^n, n being the number of characters considered as stated by Mendel), different forms of zygotes represented by the symbols AA BB, AA bb, aa BB, aa bb, AA Bb, Aa BB, Aa bb, aa Bb and Aa Bb, and there would be four (2^2) different forms of gametes, *viz.*, AB, Ab, aB and ab.

In the model the strings of beads representing the gametes should be in pairs, one string for the determiners of each character. Since there are four different forms of gametes there should be four pairs of strings. The four vertical pairs would cross the four horizontal ones and thus there would be sixteen groups of crossing, each group consisting of four crossings. The formation of zygotes is represented in the central square by moving the requisite beads to the points of intersection. If it is desired to reproduce the conventional arrangement when demonstrating the effect of selfing of AaBb or of crossing of a zygote AaBb with another which is also AaBb, the four types of gametes on the four pairs of strings should be arranged in the order **AB, Ab, aB** and **ab** from left to right on the vertical strings, or from above downwards on the horizontal strings.

In the demonstration of the working of three characters taken conjointly, there would be twenty-seven (3^3) possible forms of zygotes to be considered. These may be arranged as follows though any other order would serve the purpose.

Group I	AA BB CC		
,, ,,	AA BB cc	AA bb CC	aa BB CC
,, ,,	AA bb cc	aa BB cc	aa bb CC
,, ,,	aa bb cc		
Group II	AA BB Cc	AA Bb CC	Aa BB CC
,, ,,	AA bb Cc	aa Bb CC	Aa BB cc
,, ,,	aa BB Cc	AA Bb cc	Aa bb CC
,, ,,	aa bb Cc	aa Bb cc	Aa bb cc
Group III	AA Bb Cc	Aa BB Cc	Aa Bb CC
,, ,,	aa Bb Cc	Aa bb Cc	Aa Bb cc
Group IV	Aa Bb Cc		

In the model, **ABC** are represented by three kinds of beads which differ in colour, shape, and size, and **abc** by corresponding beads which are colourless. The twenty-seven genotypes fall into four groups according to their behaviour in breeding when selfed and I have assigned to each of them a separate corner in the model. In the first group there are eight genotypes which are quite constant. These are placed in the left-hand top corner. The second group which contains twelve forms includes genotypes in which one of the three characters will split. The third group of six forms contains two of the three characters splitting. The last group which contains only one form has none of the characters constant. The above grouping also brings out the frequency of the occurrence of different forms when Aa Bb Cc is selfed. The resulting combinations form a series of 64 in which the eight genotypes of the first group appear once only, the twelve genotypes of the second group appear twice only, the six types placed in the third group appear four times, and lastly, the single type in the fourth group appears eight times The following table makes this point clear :—

8×1	8
12×2	24
6×4	24
1×8	8
	64

If it is desired to bring out the phenotypic composition as well, it may be done by adding eight squares to the model in any fashion whatever. I would suggest their provision in an oblong frame with eight compartments added to the model at the top of it. The twenty-seven genotypes may be arranged in eight phenotypic groups as follows :—

1. Phenotype ABC having eight genotypes.
   AA BB CC
   AA BB Cc   AA Bb CC   Aa BB CC
   AA Bb Cc   Aa BB Cc   Aa Bb CC
   Aa Bb Cc
2. Phenotype ABc having four genotypes.
   AA BB cc   AA Bc cc   Aa BB cc   Aa Bb cc
3. Phenotype AbC having four genotypes.
   AA bb CC   AA bb Cc   Aa bb CC   Aa bb Cc
4. Phenotype aBC having four genotypes.
   aa BB CC   aa BB Cc   aa Bb CC   aa Bb Cc
5. Phenotype Abc having two genotypes.
   AA bb cc   Aa bb cc
6. Phenotype aBc having two genotypes.
   aa BB cc   aa Bb cc
7. Phenotype abC having two genotypes.
   aa bb CC   aa bb C
8. Phenotype abc having one genotype.
   aa bb cc

So far I have dealt with simple factors. An effective demonstration of complementary factors is obtained by using tiny bits of sponge dipped in appropriate chemical solutions instead of beads. Thus bits of sponge dipped in phenolphthalein and caustic potash solutions may be used to demonstrate the production of coloured flowers by crossing two white forms. Other phenomena of Mendelian inheritance such as cumulative factors, inhibitory factors and gametic coupling can as well be demonstrated on the same principles. I propose to deal with these in detail in a subsequent paper, as also with the modification required to be made when the recessive characters are supposed to be due to the presence of definite recessive determiners.

THE CORRELATION OF RAINFALL AND THE SUCCEEDING CROPS WITH SPECIAL REFERENCE TO THE PUNJAB.*

BY

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Introductory. In the first application of the method of correlation to the problem of the numerical measurement of the dependence of crops on rainfall in India, only the general effect of the whole summer and winter rainfalls on the autumn and spring harvests respectively was considered. In the present paper the effect of the distribution of rainfall in time is more specifically dealt with, and, too, the more important crops have been treated separately; both being very necessary steps towards the complete determination of the character of the harvest from the antecedent rainfall.

Increasing attention has been devoted of late years to attack on the same problem by similar methods in other countries, more particularly in America, and there has been obtained a sufficient number of high coefficients of correlation to encourage further investigation on the same lines.†

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* This paper is also published as a Memoir of the Meteorological Department of the Government of India.

† The more notable values obtained hitherto are:—

(1) A double correlation coefficient of +·80 of Spring rain and accumulated temperature with outturn of hay from clover and rotation grass for Eastern England. Hooker.—*Journal Roy. Stat. Soc.*, 15-1-1907.

(2) A total correlation coefficient of +·73 between the rainfall of October to March and the unirrigated matured area of the Spring harvest for the Sialkot district of the Punjab, and a double correlation coefficient of +·80 for similar data for the Delhi district. Jacob.—*Memoirs of the Asiatic Society of Bengal*, 3-2-1909.

(*Continued on page* 87).

The tract selected : Jullundur Tahsil. The tract I have dealt with is the Jullundur Tahsil of the Jullundur District situate in the Doaba between the rivers Beas and Sutlej. The area of the Tahsil is 428 square miles of which practically 390 are cultivated, and it is divided into three Assessment Circles, which are roughly homogeneous in respect of their soil, climate, and their courses of husbandry. There are no canals and as a rule very little flooding, so that the problem of rainfall effect is not too complicated. But there is a very large number of wells, and during the last 30 years more wells have been steadily added to both the Dona Lehnda and Dona Charhda Circles, and this means that there is a concomitant diminution of unirrigated crops, for which allowance has to be made in considering the variation in the areas sown each harvest on unirrigated land. Thus in the Dona Charhda Circle every fresh well sunk has meant that on the average 2·2 acres cease to be classed as unirrigated for the purposes of the Spring harvest. Of this diminution a loss of :—

0·66 acres per new well falls on unirrigated wheat sown,
1·20 ,, ,, ,, ,, wheat and gram,
0·18 ,, ,, ,, ,, gram alone,
and the balance of ·16 acres on other crops.

The countervailing gain in Spring irrigated crops is however no less than an additional 7·4 acres for each additional well, of which 3·36 acres per well, or rather less than one-half, has been an increase in wheat sowings. Before the correlation of the areas sown with the rainfall are worked out, the crude figures must in all cases be corrected by the appropriate factors, these being slightly different for each of the three Assessment Circles.

Distinction between the two problems—sown area and yield. Two entirely distinct problems present themselves if we propose

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(3) A correlation of −·69 between accumulated temperature and potato yield Warren Smith.—*U. S. Monthly Weather Review,* May 1911.

(4) A correlation of −·70 between the effective rainfall of July 21 to August 20, and the yield in corn in Ohio. Warren Smith —*U. S Monthly Weather Review,* February 1914.

(5) A correlation of ·88 between rainfall and temperature in April to September and the yield of cotton in Texas. J. B. Kincer —*U. S. Monthly Weather Review,* February 1915.

to forecast the amount of crop of any harvest, and these are :—

(1) The determination of the area sown with each class of crop.

(2) The determination of the percentage of the crop which is likely to come to maturity, or, in other words, the yield or outturn per unit of area.

The first problem, which is, for not too great a cycle of years, in the main a problem of rainfall and temperature, is also an economic and psychological problem—prices of seeds, scarcity of labour, population, mortality, the standard of living, the number of plough cattle, mechanical aids to cultivation, and political events—all having contributory effects. Yet, unless the fluctuations in these subsidiary causes are very violent, they will not mask the first order effect of rainfall, and the proper method is to deal with the large effects first, and then proceed to disentangle the residual effects. This is the invariable scientific practice in those cases, for example in astronomy, in which we cannot control the phenomena.

The second problem, the determination of the yield of each crop per acre, is much less an enonomic problem than the preceding one, especially in dealing with unirrigated crops which are not much manured or weeded, and is really a joint problem of meteorology, subsoil physics, and plant biology. It is a statistical problem only on account of its complexity ; and the more physical and biological laws can be applied to it, the smaller will be the residual unexplained effects to which it will be necessary to apply statistical methods.

PREDICTION OF AREAS SOWN.

Correlation of rainfall and sown areas. I take first the problem of predicting the extent of sowings, and give the total correlations of some only of the crops which have been considered for each Assessment Circle, namely, for *chahi* (well-irrigated) wheat, wheat and gram unirrigated, and all unirrigated crops together, for the Spring harvest based on the figures of the thirty years 1886-1915.

The correlations are :—

		July	August	September	October
Chahi wheat ...	Dona Lehnda ..	−0·38	−0·25	−0·52	......
	,, Charhda ..	......	−0·28	−0·53	−0·34
	Sirwal	... ..	−0·01	−0·50	−0·39
Barani wheat and gram.	Dona Lehnda ...	0·18	0·21	0·54	...
	,, Charhda ...	.. ...	0·13	0·54	0·19
	Sirwal	......	0·16	0·27	.. ..
All Barani Spring crops.	Dona Lehnda ...	0·21	0·04	0·37	...
	,, Charhda ...	... ..	0·17	0·48	0·33
	Sirwal	......	−0·06	0·48	... ..

The July and August coefficients are in the neighbourhood of 0·20 with a probable error of ± 0·12, or, on the simple theory of probability, the odds in favour of these correlations being significant are 7 to 1. The simple theory, however, by no means gives a favourable enough estimate of the odds when we find coefficients of about the same magnitude repeated again and again. In fact the repetition of the correlations for three different areas, supposing the sown areas in each case are unassociated except on the score of a more or less common rainfall, makes the odds nearly 350 to 1. So that I think that we may justly conclude that the correlations with July and August rainfalls are significant. In any case it is highly probable that they are significant, as the rainfall in these months is a true contributory cause of the autumn sowings of September, October, and November.

The correlations of sown area with September rain are in the neighbourhood of 0·50 with a probable error of ± 0·09, so that the simple odds in favour of the significance of this correlation are over 80,000 to 1, so that this coefficient is undoubtedly significant. The frequency with which nearly the same value of the correlation is found for this and other districts of the Punjab makes the odds much greater even than this.

The correlations for October are on an average about 0·23 with a probable error of ± 0·11, or the odds in favour of their significance are 18 to 1.

A further point of importance with regard to the correlation with September rain is that the odds are 9 to 1 against its being as low as 0·325, and we are not likely to be wrong if we say that it lies between 0·4 and 0·6. For lower correlations we cannot predicate such narrow limits between which the correlation coefficient is likely to lie.

The coefficients are the simple or so-called total correlation coefficients, but they do not represent the actual rainfall effect and it is necessary to eliminate the error due to the fact that the rainfalls in the different months are themselves correlated, and so it is possible that the area sown is spuriously correlated with the August rainfall simply because it happens to depend on the September rain, which in its turn is correlated with the August rainfall.

If the rainfalls in August, September, and October (July rainfall has been left out of account because of the doubt of the magnitude of its effect on autumn sowings) are positively correlated *inter se*, then this fact will have given a fictitiously high value to all the correlations ; but, if on the other hand the rainfalls are negatively correlated among themselves, the true magnitude of the crop correlations will have been masked, and we may have considerably to increase the total correlations previously found. This latter is actually the case. The correlations of the rainfalls are :

August with September	−0·37
,, ,, October	−0·10
September with October	−0·13

So that it is clear that the true or so-called net coefficients of correlation are markedly larger than the values previously stated. The valuation of the net coefficients of correlation is a somewhat laborious process, and for the Jullundur data I have limited myself to the two cases of greatest interest, namely, for well-irrigated wheat and for all unirrigated crops together.

Prediction for Chahi wheat. I take firstly the case of well-irrigated wheat in the Dona Charhda Circle for which the average area sown in the last 30 years is 19,100 acres, with a standard deviation of 4,080 acres or 21·3 per cent. The net correlations of the area sown each autumn are as follows :—

With August rainfall	−0·79
,, September ,,	−0·86
,, October ,,	−0·74

These average at about 0·80 with a probable error of ± 0·08, and the odds are thus over 20 to 1 against the coefficients being as low as $-0{\cdot}60$ in absolute value, and nearly 200 to 1 against their being as low as $-0{\cdot}5$, so that we may say that these coefficients are almost certainly greater than 0·6.

From these correlations we determine the equation expressing the area sown with wheat on well-irrigated lands in terms of the rainfall departures from the mean, namely:—

$$S' = 18{,}890 - 570\ D_8 - 750\ D_9 - 4{,}300\ D_{10},$$

where D_n is the departure of the rainfall of the *n*th month from the average rainfall of the month.

The equation shows what an enormous effect rain in October has in causing the cultivator to abandon wheat sowings on well-irrigated lands: in fact an inch of rain in October would throw out nearly 6 acres of well-irrigated wheat, as against one acre thrown out by an additional inch of rain in August.

The equation must not, however, be interpreted to mean that every successive increment of rain will throw out further equal amounts of well-irrigated wheat, as the relation between the rainfall and the area sown is certainly not linear when we come to large departures from the average. All that we can assert from the equation is that rainfall of the quantity and distribution that fell during the years 1885—1914 in August, September, and October did, on the whole, have the effects noted. Of course in considering what effects rainfall in the different months has on well-wheat sowings we must remember that it is much more usual to have a departure of one inch of rain in August or September than in October, and properly to compare the effects of rainfall as it did occur in the last thirty years we must multiply the regression coefficients of each month by their respective average rainfalls. We find thus that actually the relative effects of August, September, and October rainfall were as 2 : 3 : 1, the reason for the low October effect being due to the fact that it is the exception to get rain in October at all. If it does fall it has, as we have seen, a much greater effect than rainfall in the previous months in diminishing sowings of well-irrigated wheat.

When the appropriate correction for the number of wells has been introduced the final formula of prediction for the sown area of *chahi* wheat is :—

$$S = 3{\cdot}6\,(w\text{-}5540) + 26{,}910 - 570R_8 - 750R_9 - 4300R_{10},$$

where R_n is the total rainfall in the nth month, and w is the number of wells in the Assessment Circle.

The multiple coefficient of correlation of sown area and the 'weighted' area is 0·89, so that the prediction formula, so far as a linear expression can give the relationship, is a good one.

From this formula the sown area has been calculated for each year from 1885—1914 and the results are shown graphically in Diagram I, which shows also the actual sown areas.

The correspondence between the observed and calculated results is seen to be distinctly close. The probable error of the prediction is $0{\cdot}67 \times \sigma_{1\cdot234} = 1050$, or 5·6 per cent. of the mean.

Constancy of other crops. A very important fact may here be referred to, namely, that if we group together all well-irrigated Spring crops excluding wheat, and wheat and gram and form a class of 'other crops' which consists mainly of the fodder crop, senji, melon, tobacco, and other vegetables,* the sown area of this class after the correlation for numbers of wells has been applied is remarkably constant from year to year having a coefficient of variation of only 5·9 per cent. as against one of 21·9 per cent. for well-irrigated wheat, so that the prediction from an appropriate rainfall formula would have a probable error of about 2 per cent. only.

Prediction for all barani rabi crops. The next case treated is that of all unirrigated (*barani*) Spring crops taken together.

The prediction of the sown areas of individual unirrigated crops is very desirable, but except for the principal crop, wheat and gram combined, the problem will require a finer analysis than by the total rainfall of the month. Thus the 30th of September is a critical time. If sowing conditions are favourable before that date, a great deal of gram is likely to be sown, but if suitable rain falls after that, gram is almost always combined with wheat. Wheat

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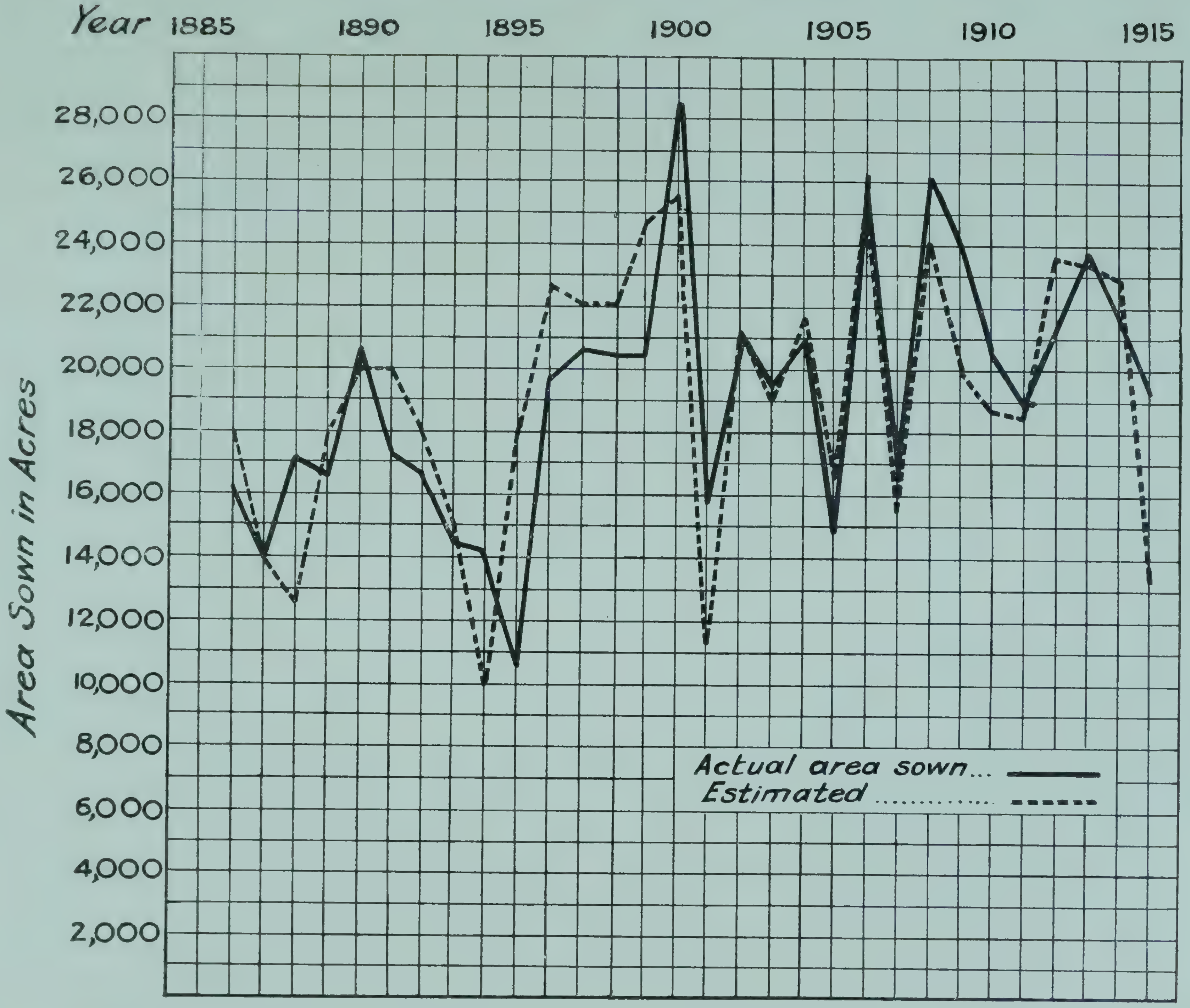
* This group of crops consists of those grown for local consumption of man and beast and are very little affected by external supply and demand.

DIAGRAM I.

Dona Charhda CHAHI WHEAT.



in particular requires very favourable conditions if it is to be sown on *barani* land, and an examination of monthly rainfall does not suffice to show the fluctuations in the area sown, which in all three parts of the Tahsil shows a steady fall from 1885 onwards with a minimum between 1900 and 1905 and a very marked rise in the last 10 years.

The regularity of the change suggests a secular cause such as Dr. Shaw's 11 years' periodicity from wheat in England. At any rate the general trend of the data can be fitted with a smooth curve.

Parabolas fitted by the method of least squares are fair representations, but would certainly break down for extrapolation purposes.

For the sown areas of all unirrigated Spring crops together the net correlation coefficients are :—

With August rainfall = + 0·57
,, September ,, = + 0·72
,, October ,, = + 0·59

The combined coefficient of correlation is 0·77 so that fair prediction is to be anticipated. Taking the coefficients of the linear regression formula, and multiplying them by the appropriate constant, the expression

$$\cdot147\ R_8 + \cdot53R_9 + 2\cdot66R_1$$

is obtained which may be called the weighted rainfall. If the weighted rainfall is taken as the abscissa and the area sown corrected for the number of wells as ordinate we get a distribution of the kind as shown in Diagram II which clearly indicates that to a second approximation the data can be fitted with a curve of the form

$$y^n = ax - bx^2,$$

and after a number of trials the curve

$$y^3 = 34x - 1\cdot7x^2$$

was found to be a fair but not a good approximation to the changes. The curve rises abruptly at the origin, but it would have been better to make it rise abruptly at 2″ of the rainfall, which is about the minimum required for any sowings at all. It reaches a maximum at 30″ of weighted rainfall, that is to say, beyond that, more rainfall would interfere with sowings. About the same maximum was found for data in the old Delhi District. The problem however must be attacked by a systematic curve-fitting method, which should substantially reduce the probable error of prediction which is 0·675 × 5700 = 3840 acres or 9 per cent. of the mean, an appreciably larger error than in the case of irrigated wheat, although the coefficient of variation is about the same, 22 per cent., in both cases. Even as it is, the prediction afforded is a distinct advance on existing practice.

Prediction of Outturn.

Nature of problem. The next step after finding out how much crop is sown is to find out how much of it is going to come to maturity, and that is as for human beings, both a bathmic and an environmental problem, condition of seed, state of the seed bed, and the treatment and climate from the time of sowing to the time of harvesting, being the factors to be taken into account.

In the present paper unirrigated wheat only is dealt with by the statistical method, and the condition of seed has not for the moment been taken into account; but the state of the seed bed which depends, in the main, on the September and October rainfall, is taken into account as well as the rainfalls in each of the subsequent winter months, November to March.* The antecedent rotational crop which is a very important factor in considering individual fields is a quite subsidiary point in the aggregate over such a large area as an assessment circle, in which there will be many fields in different stages of the crop rotation. As a matter of fact, unirrigated wheat is generally sown after a 10 months fallow and is followed by *charri*, *moth*, or *guara*, in the subsequent June or July (*dofasli dosala*) or on the better class of unirrigated (*barani*) soils, wheat is sown year after year (*ek fasli ek sala*) with no intermediate crop. The outturn is determined in the Punjab Revenue Papers from the

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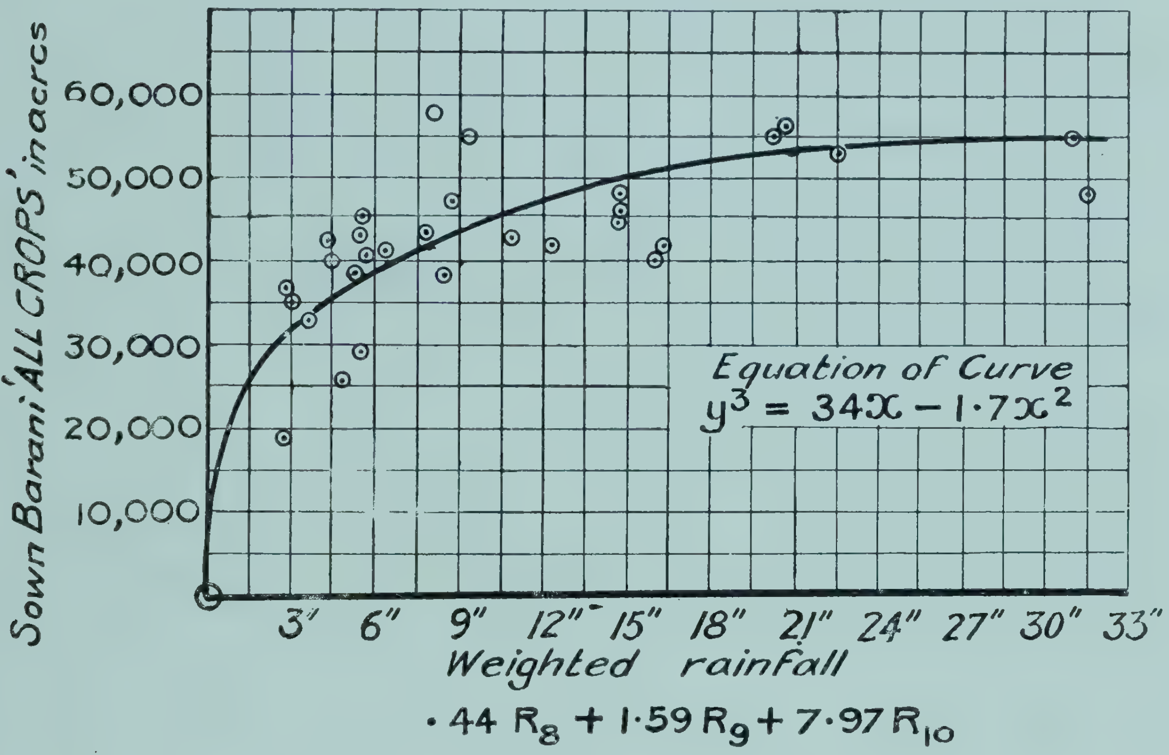
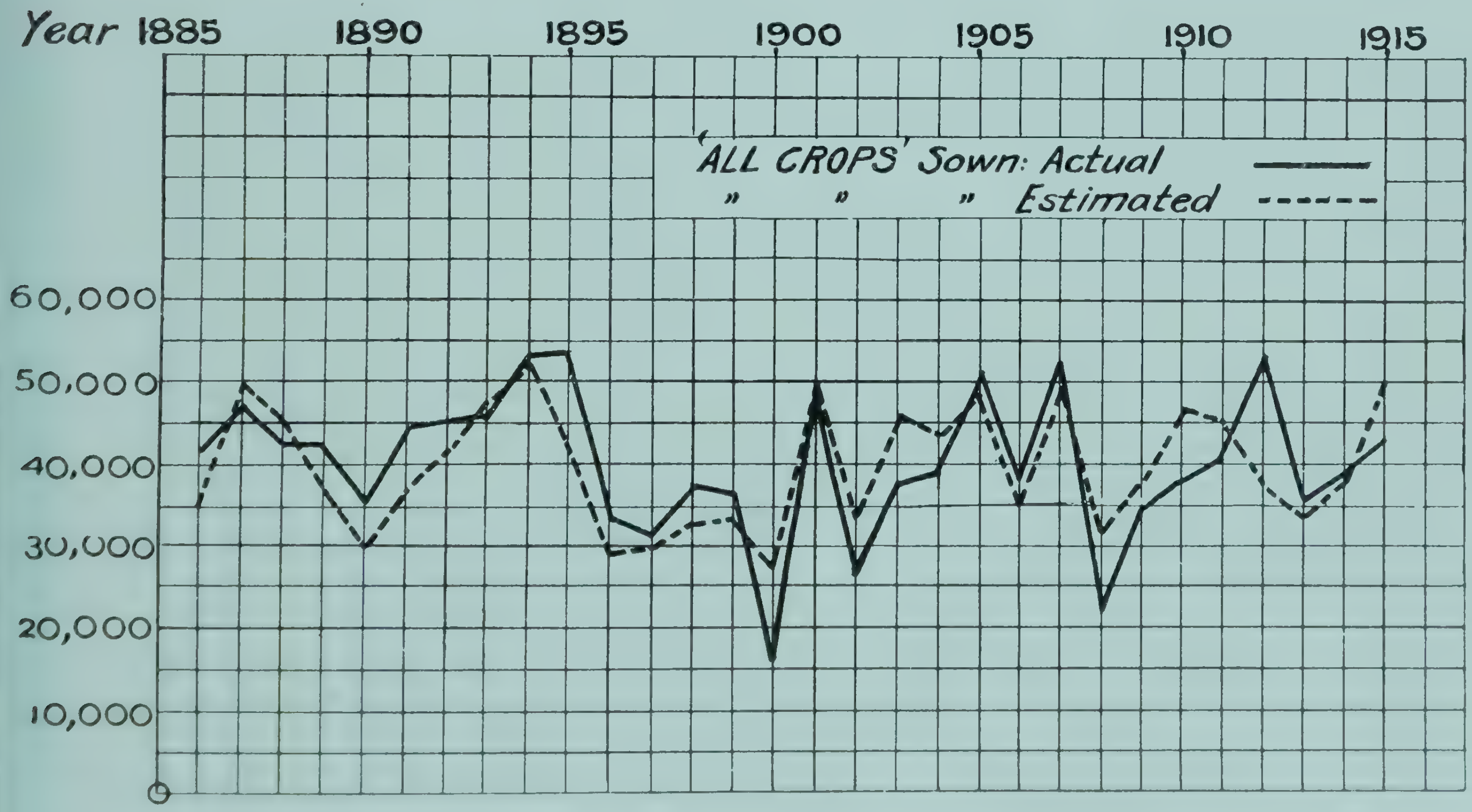
* An analysis which aimed at completeness would naturally include not merely rainfall but all climatological factors, such as temperature, sunshine, precipitation in the form of dew, evaporation, wind, and so forth, defect or excess of which may on occasion reduce an otherwise promising crop to a very poor condition. Given the opportunity the analysis can be so completed.

DIAGRAM II.

Dona Charhda ALL BARANI RABI CROPS SHOWN.





area of the crop which fails to come to maturity, the so-called *kharaba* which is merely the Patwari's estimate of the deficiency of the particular field below what he considers a normal value.

His estimate is checked by various Revenue officials of higher grade, but it still remains subject to a very large personal equation. In particular during the last 15 years there has been much greater liberality in allowing *kharaba*, and in dealing with the statistics the last 30 years have been divided into two periods. The results based on the second period are probably the more reliable. Crop experiments are, as at present conducted, of a very perfunctory kind, and two or three of them for each principal crop per Tahsil, would be required to get results truly indicative of the character of the harvest. It is much to be regretted that a proposal to do away with crop experiments altogether has been mooted. It is quite as important that accurate outturns should be determined for crops grown by cultivators under normal conditions, as for crops grown for special test purposes by the Agricultural Department.

Prediction by multiple correlation. Taking the figures for *kharaba* as we have them the correlations of rainfall and failed area for the various crops are :—

Correlations of percentage kharaba with rainfall in the winter months.

	Assessment Circle	September	December	January	February	March
Chahi wheat ...	Dona Lehnda ...	......	-0·36	-0·19	-0·27	-0·27
	,, Charhda ...	-0·41	-0·46	+0·01	-0·21	-0·36
	Sirwal ...	......	...	......	......	...
Chahi all crops ..	Dona Lehnda .	......	....	......	.....	.....
	,, Charhda ..	-0·46	-0·39	-0·18	-0·25	-0·43
	Sirwal ...	-0·08	-0·05	+0·17	-0·02	-0·15
Barani wheat ...	Dona Lehnda ...	...	-0·31	-0·16	-0·19	-0·07
	,, Charhda ...	-0·37	-0·40	0·16	-0·26	-0·26
	Sirwal ..	-0·12	-0·07	+0·23	-0·02	-0·14
Barani wheat gram ...	Dona Lehnda	....	-0·13	-0·14	-0·19	-0·23
	,, Charhda ...	-0·37	-0·34	-0·19	-0·31	-0·35
	Sirwal ...	-0·54	-0·33	-0·11	-0·37	-0·41
Barani gram ...	Dona Lehnda ...	......	......	...	......	.....
	,, Charhda ...	-0·43	-0·51	-0·19	-0·31	-0·35
	Sirwal ...	.....	...	.....	....	...
Barani all crops .	Dona Lehnda ..	.....	-0·23	-0·20	-0·14	-0·22
	,, Charhda ...	-0·40	-0·40	-0·17	-0·32	0·24
	Sirwal ...	-0·42	-0·32	-0·07	-0·26	-0·28

The Dona Lehnda results are for the 30 years 1886-1915. For Dona Charhda and Sirwal for 1901-1915.

A noticeable feature of the figures is the high negative correlation with September rainfall, additional evidence, were any necessary, of the value of a moist seed bed for germination.

I have not had sufficient time at my disposal to discuss in great detail the results for all three Assessment Circles, and for this reason it was necessary to limit the further analysis to a single crop and a single assessment circle. Accordingly the most important crop, wheat, has been selected, and that Assessment Circle in which the rain gauge is situated.

I emphasize only the Dona Charhda figures for unirrigated wheat which are :—

	September	December	January	February	March
Whole period 1886—1915	−0·30	−0·30	−0·27	−0·19	−0·24
First „ 1886—1900 ...	−0·25	−0·25	−0·46	−0·02	−0·19
Second „ 1901—1915 ...	−0·37	−0·40	−0·16	−0·26	−0·26

These figures are consistent *inter se* and with all the other Circles and crops and their significance is accordingly greater than it would be if measured merely by their probable errors.

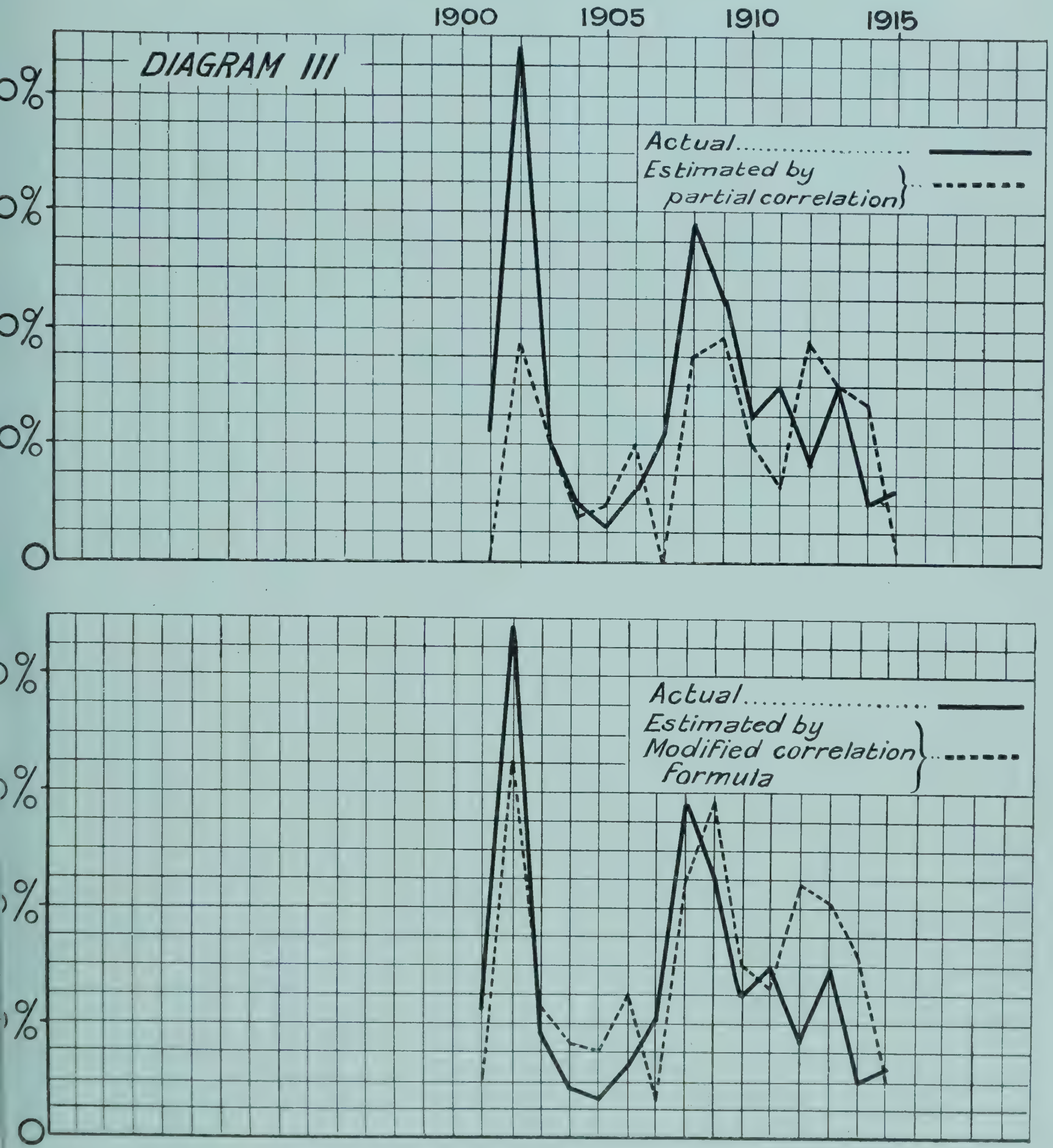
On the figures of the last 15 years I have calculated a provisional regression formula based on the erroneous assumption that the rainfalls in these five months are not correlated to each other.

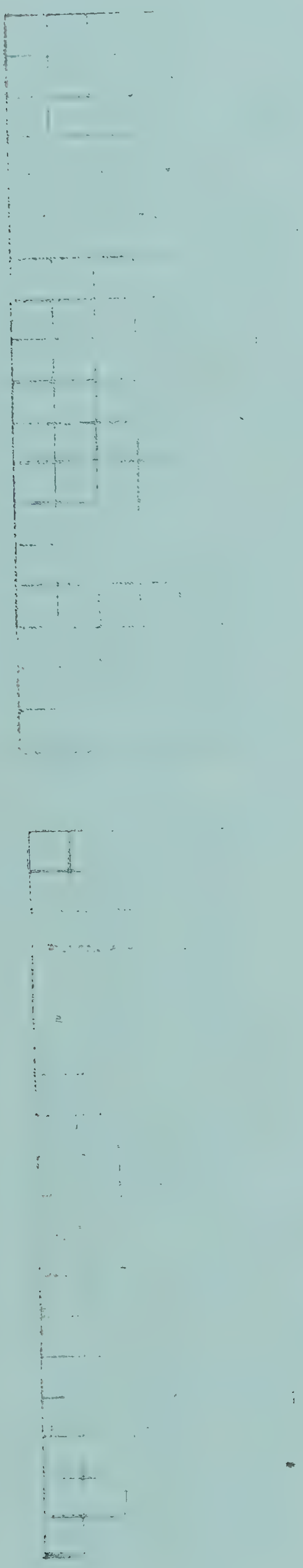
Actually there is no significant correlation between the rainfalls of December and February, January and February, February and March.

In fact the February rainfall seems a very detached effort, but there is a substantial correlation in the rainfalls in the other months. The concordance between calculation and fact is shown in Diagram III. The agreement would have been much better had these mutual rainfall correlations been taken into account, but a multiple regression formula based on six variables takes a long to evaluate time and on account of pressure of much other work I had to abandon it.

Kincer's method. Moreover, Dr. Simpson having drawn my attention to an alternative, and in some ways a preferable method

Dona Charhda. WHEAT KHARABA.





of dealing with the problem, developed by J. B. Kincer in the *U. S. Monthly Weather Review* of February 1915 for dealing with the yield of cotton in *Texas*, it seemed of importance to apply the method to yields of Indian crops. Kincer's results being so good that a correlation of 0·88 is obtained.

Kincer assumes that the most favourable conditions for cotton are the normal ones, and that any departures from these, whether above or below, whether of rainfall or temperature, are harmful. There would seem to be *a priori* justification for this in dealing with a crop with centuries of development in a single place behind it, but expert opinion would be advisable before adopting it for Indian crops particularly for imported plants.

Kincer adopts certain numerical values for the harm done by rain, or heat, or cold, according as a plus deviation follows a plus deviation, a minus a minus, and so on, thus :—

	RAINFALL					
	April	May	June	July	August	September
+ following + or 0 ...	4	8	8	4	4	4
+ ,, − ...	4	4	2	2	2	3
− ,, − ...	4	5	6	8	10	8
− ,, 0 or + ...	2	2	3	6	8	4

Naturally a sequence of months with the same departure from normal is weighted as the most harmful.

He has a similar table for temperature :—

	April	May	June	July	August	September
+ Temperature with 0 or + rain.	1	1	1	1	1	1
+ T with − R	1	1	2	2	2	1
− T with − R	1	3	2	2	2	2
− T with + R	1	4	4	2	2	2

He has in addition certain slight modifications of the value to be introduced when during several months the same conditions obtain.

The values are stated "to have been fixed empirically from a general knowledge of the effect or plant development of certain combinations of weather," but what constitutes a plus, zero or a minus departure is not stated except that 0·3 of an inch of rain less than the normal for April or May is considered as minus.

Application of Kincer's method to unirrigated wheat. In applying Kincer's method to the yield of unirrigated wheat in Jullundur District, it seemed much better to assume that all departures of rain above the normal are beneficial and *vice versâ,* not because this is true for all crops in all places, but because with the soil and rainfall which actually obtain in that district, it is very rare for excess of rain to be markedly harmful.

In order to make the scheme as little arbitrary as possible the rainfall distribution curves have been plotted for each month, and divided into three equal areas which are marked – , O, + respectively.

The trichotomy is exhibited in the accompanying Diagram IV. Thus :—

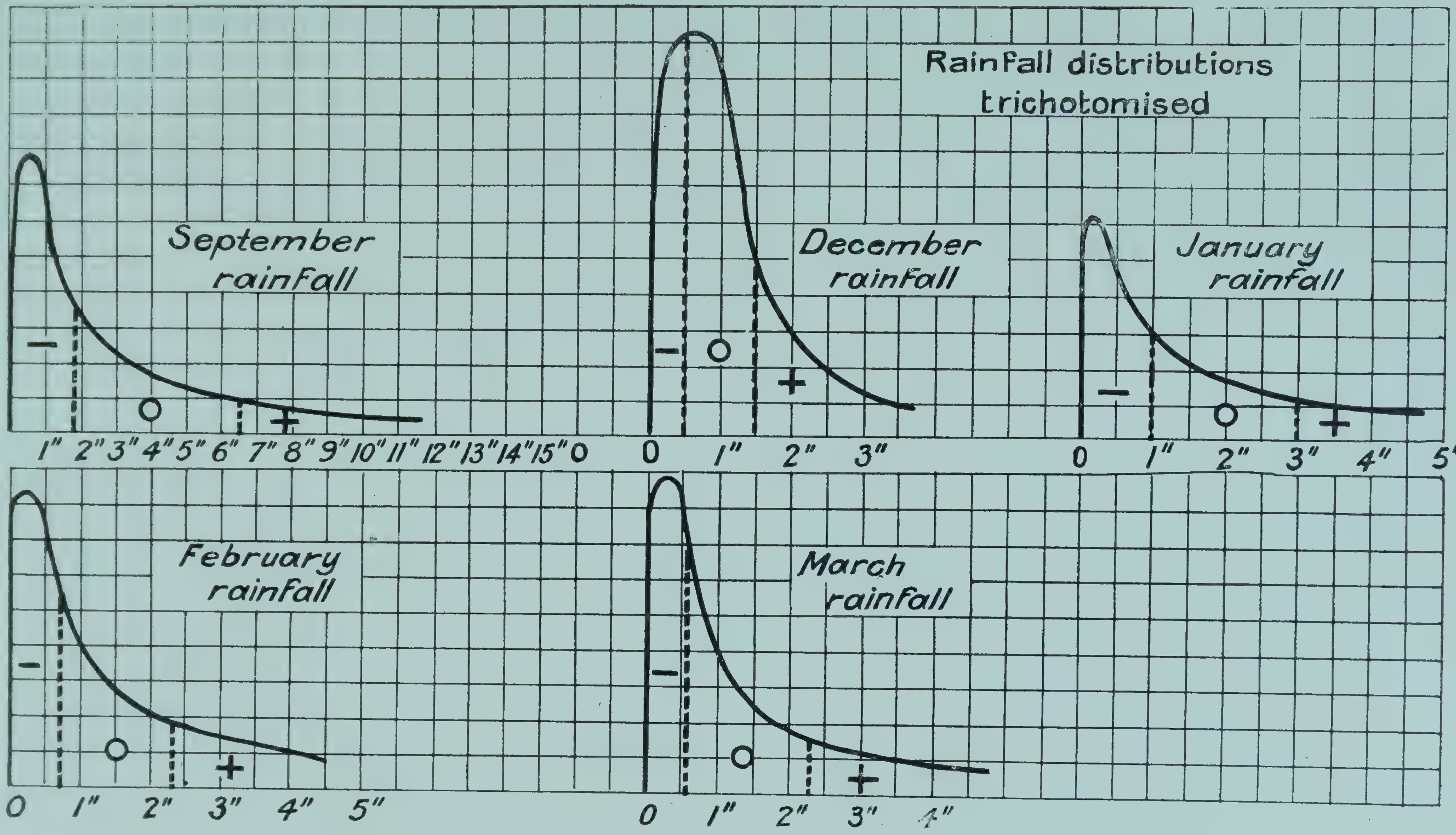
	–	0	+
	Less than	Between	Above
September ...	1″·8		6″·5
October ...	0″·1		0″·5
November ...	0″·1		0″·5
December ...	0″·5		1″·5
January ...	1″		3″
February ...	0″·7		2 ·3
March ...	0″·6		2″·2

Rainfalls in each month are then weighted according to the following scheme (September rainfall weight = 5).

Rain departure for September	Benefit of October and November rain
+	0
0	0
–	20

	Benefit of December rain.
+	1
0	2
–	3

DIAGRAM IV.


Rainfall distributions
trichotomised
September
rainfall
−
O
+
1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12" 13" 14" 15" 0
December
rainfall
−
O
+
0 1" 2" 3"
January
rainfall
−
O
+
0 1" 2" 3" 4" 5"
February
rainfall
−
O
+
0 1" 2" 3" 4" 5"
March
rainfall
−
O
+
0 1" 2" 3" 4"

	Rain departure December	Benefit of January rain
+	+	1
	0	2
	−	3
0	+	2
	0	3
	−	4
+	+	3
	0	4
	−	5

		Rain departure January	Benefit of February rain
+	+	+	1
		0	2
		−	3
	0	+	2
		0	3
		−	4
	−	+	3
		0	4
		−	5
0	+	+	2
		0	3
		−	4
	0	+	3
		0	4
		−	5
	−	+	4
		0	5
		−	6
−	+	+	3
		0	4
		−	5
	0	+	4
		−	5
		0	6
	−	+	5
		0	6
		−	7

The only modification which was necessary to this was the addition of the factor 20 to every 0 above 2 in number occurring in the months September, December, January, February and March, thus indicating that long continued normal conditions are, as in the case of cotton in Texas, very favourable.

The weighted rainfall in each month was added together, and a coefficient of benefit B obtained, and this was correlated with the area of unirrigated wheat for 1900-1915. The correlation is − 0·91.

even higher than Kincer's figure of 0·88. The formula giving the percentage of failure in terms of the coefficient B is

$$K = 24{\cdot}2 - {\cdot}35B.$$

The *kharaba* calculated from this formula is plotted with the actual figures of *kharaba* in Diagram V. I think the agreement of the two values shows that the formula is a very good one and affords *a posteriori* justification of the hypothesis.

The introduction of suitable corrections for other climatic factors, such as temperature, sunshine, evaporation, precipitation in the form of dew, wind and the like would improve the prediction still further.

BETTERMENT OF PREDICTION.

Subsoil water. The method of correlation is not a method apart, dissociated from other methods of analysing observed facts; on the contrary, the more physical and chemical laws we can make use of before we start correlating the better.

For example in forming the prediction equations for sown areas, we have correlated rainfalls in August, September, and October with the areas sown in September, October, and November, but what we really want to know is, what the cultivator has a shrewd knowledge of, when he puts in his crop, and that is the state of the subsoil moisture, and also the temperature of the seed bed.

The problem is, given the rainfall and temperature throughout the monsoon period, what is the distribution of the subsoil moisture when *rabi* sowings commence. I have been unable to find even in Leather's valuable researches the complete answer to this question. He has indeed shown,* that if evaporation is an exponential function of the time, the quantity of water in the first seven feet of Pusa soil can be found from the known temperature and humidity from September till June, but as the question of run-off, which in the monsoon is all important, is not quantitatively worked out, it does not seem possible to apply the results without further

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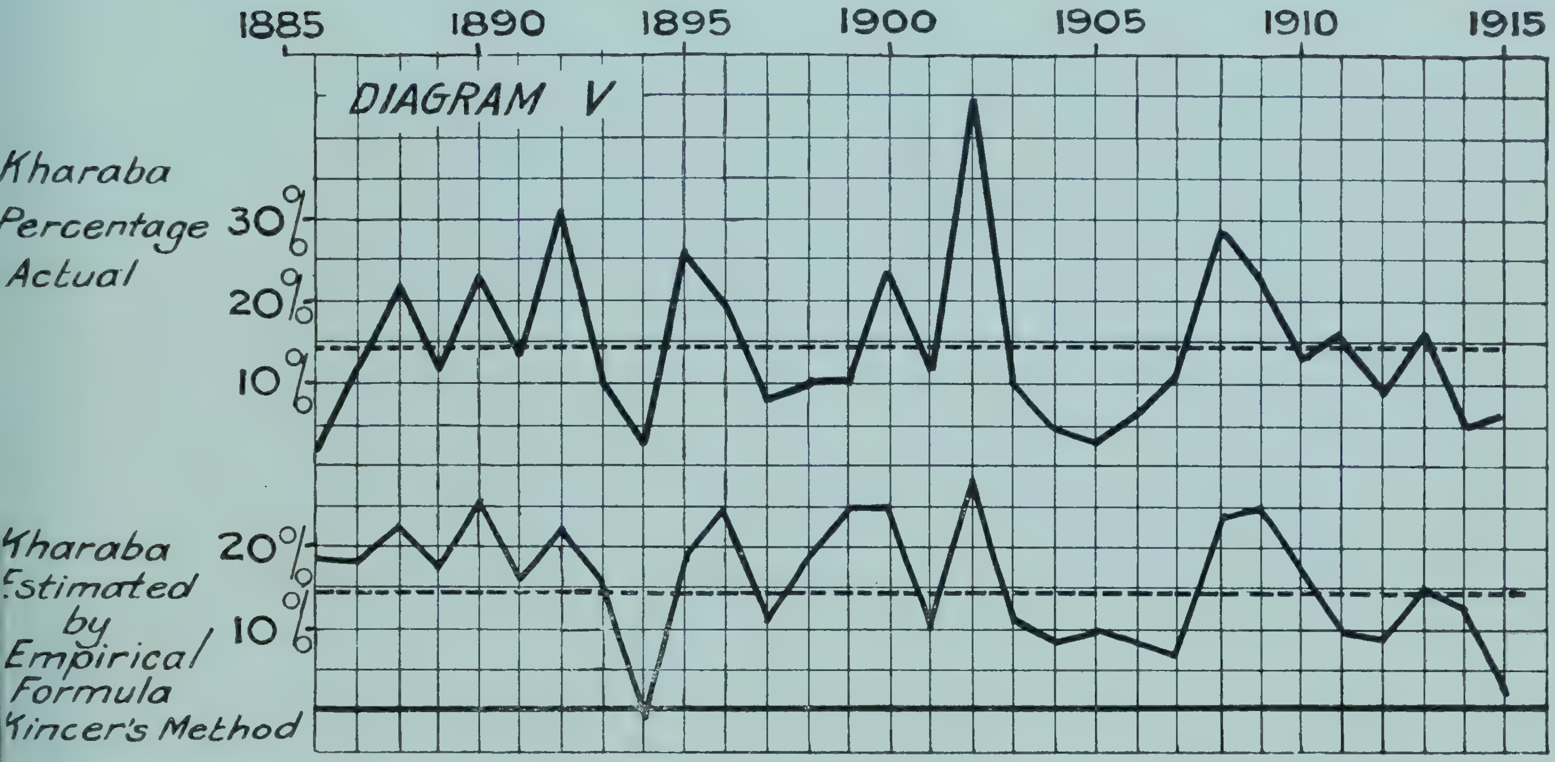
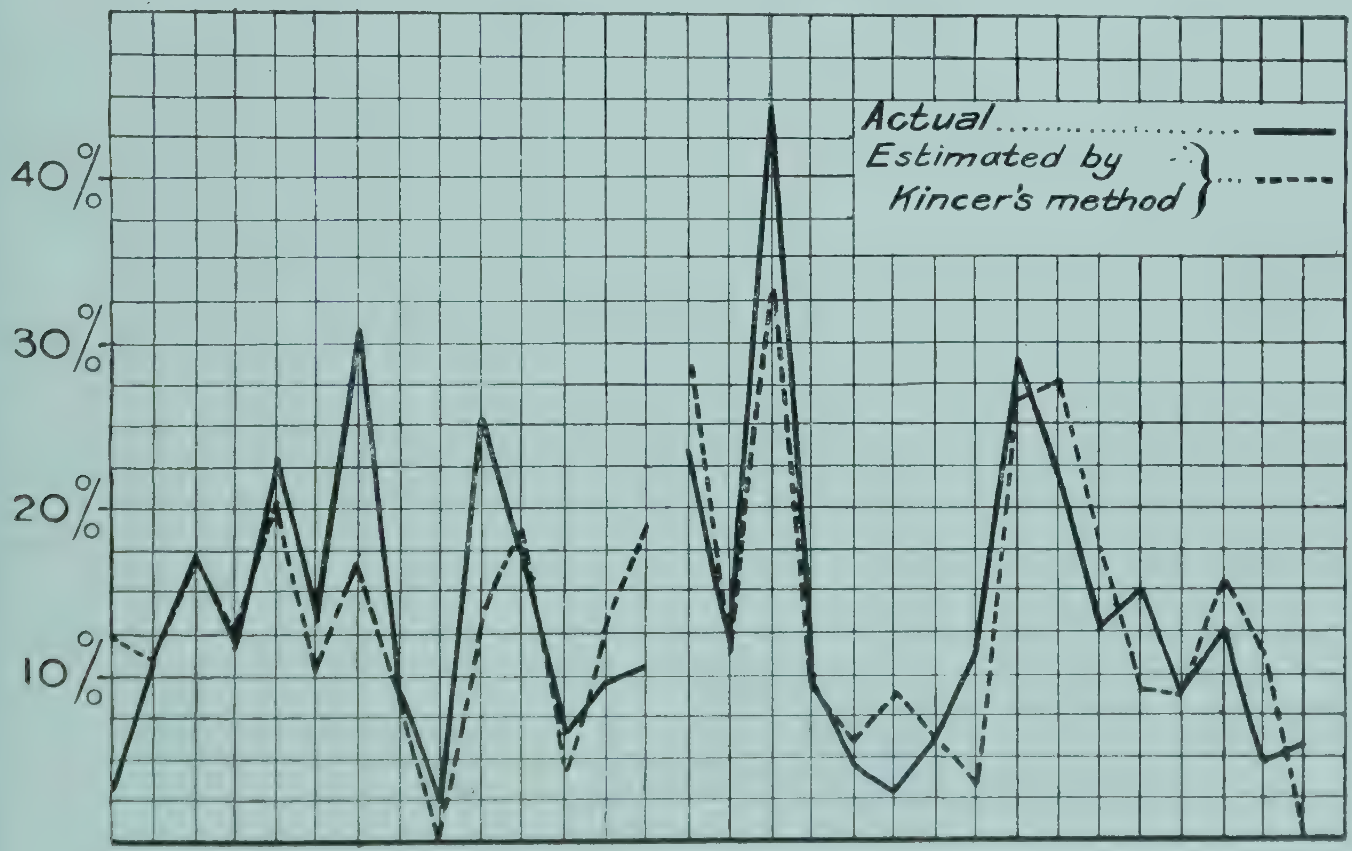
* Leather, J. W. Water requirements of crops in India. *Mem. Dept. of Agri. in India Chem. Ser.* vol. I, no. 8.

Dona Charhda WHEAT KHARABA.



WHEAT KHARABA.



experiment to the Punjab. It seems very desirable to repeat the Pusa experiments in all typical Punjab districts, and it should be possible as a result of them to state once for all a formula giving the soil moisture at the close of the monsoon, for each foot of subsoil in terms of the antecedent rainfall and the size and nature of the particles composing the soil.

The complete hydrodynamical solution of the movement of the subsoil water has not so far been obtained, but on the assumption that the velocity is proportional to the first differential of the relative saturation of the soil and that the ratio of surface of all particles per unit of volume to the saturation quantity of moisture is constant, an integrable equation results, for a linear change of particle surface with depth.

This is a great limitation. Further experiment in this country is urgently required, and from a sufficiently extended series of data assumptions could be made leading to a more or less accurate general solution.

Lastly as to the determination of yield, what we want to know is not merely what are the optima conditions of soil moisture and temperature, but what effect defective conditions have. Thus want of water in the first stage of growth is said to mean short stalk, but not necessarily small grain; in the later stages water is essential for grain development.

What is the quantitative expression of this law?

According to Warren Smith, American corn requires between 40 to 80 per cent. of the saturation value of moisture for its most favourable development, but exactly what will be the development of a plant which has, say, 40 per cent. of moisture in one month, 30 per cent. in the next, 20 per cent. in the next, 30 per cent. in the next, and so on?

In particular, what in each stage of development is the minimum requisite to support plant life.*

---

* Leather's researches throw some light on this problem, Vol. 1, No. 8 of the *Memoirs of the Department of Agriculture in India*, page 146, which shows that for unmanured wheat, an increase of soil moisture from 10 to 20 per cent. increases the grain weight by about 80 per cent.

(*Continued on page* 102).

Plant development. To sum up, the method of correlation enables us to establish prediction formulæ of both sowings and yield, which represent with accuracy the effect rainfall has on the crops. They would undoubtedly be improved by considering the effect, in particular, of prices, crop rotation and temperature, and by incorporating all established quantitative laws as to subsoil moisture and plant development. Even as it is, the formulæ obtained in this paper have a definite practical value which modern statesmanship cannot afford to ignore.

Conclusion.—In conclusion I wish to express my thanks to the kindness of Dr. Gilbert Walker and Dr. Simpson in having most of the many coefficients of correlation calculated.

Between 10 and 20 per cent. the weight of crop increases nearly in a linear fashion with increase of moisture, but though in the case of unmanured wheat diminution of outturn might be linear down to zero moisture it is certainly not so for Leather's experiments in the case of manured wheat, and in particular it is important to know what happens with greater saturation than 20 per cent. Even this preliminary knowledge for a pot culture with a percentage saturation kept constant throughout the period of development, would give a function closely correlated with the actual yield.

DIAGRAM VI.

DONA CHARHDA (Rabi Crops Sown.)

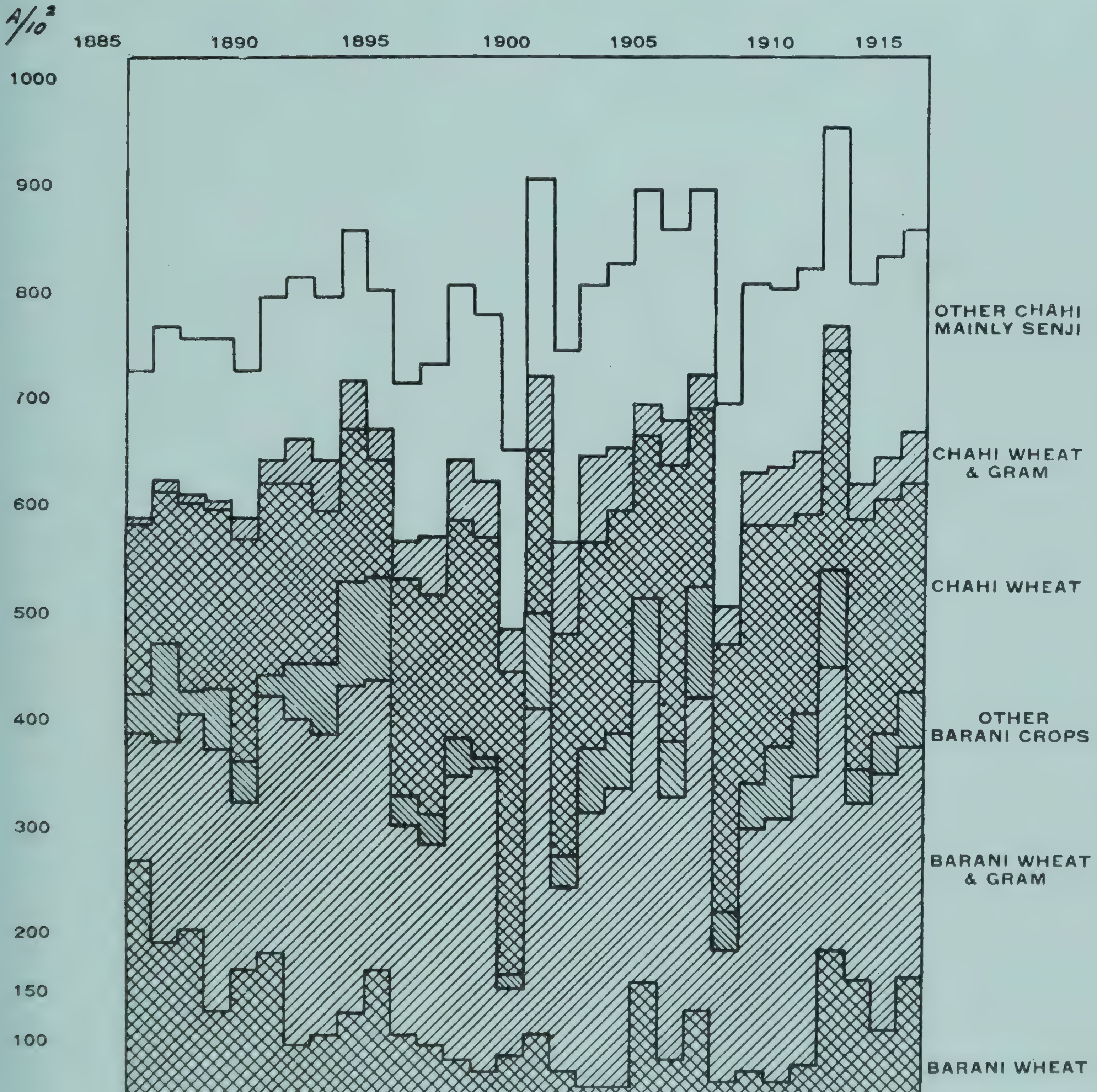


DIAGRAM VII.

Dona Charhda. (RABI CROPS SOWN)

PERCENTAGE OF EACH KIND OF CROP.

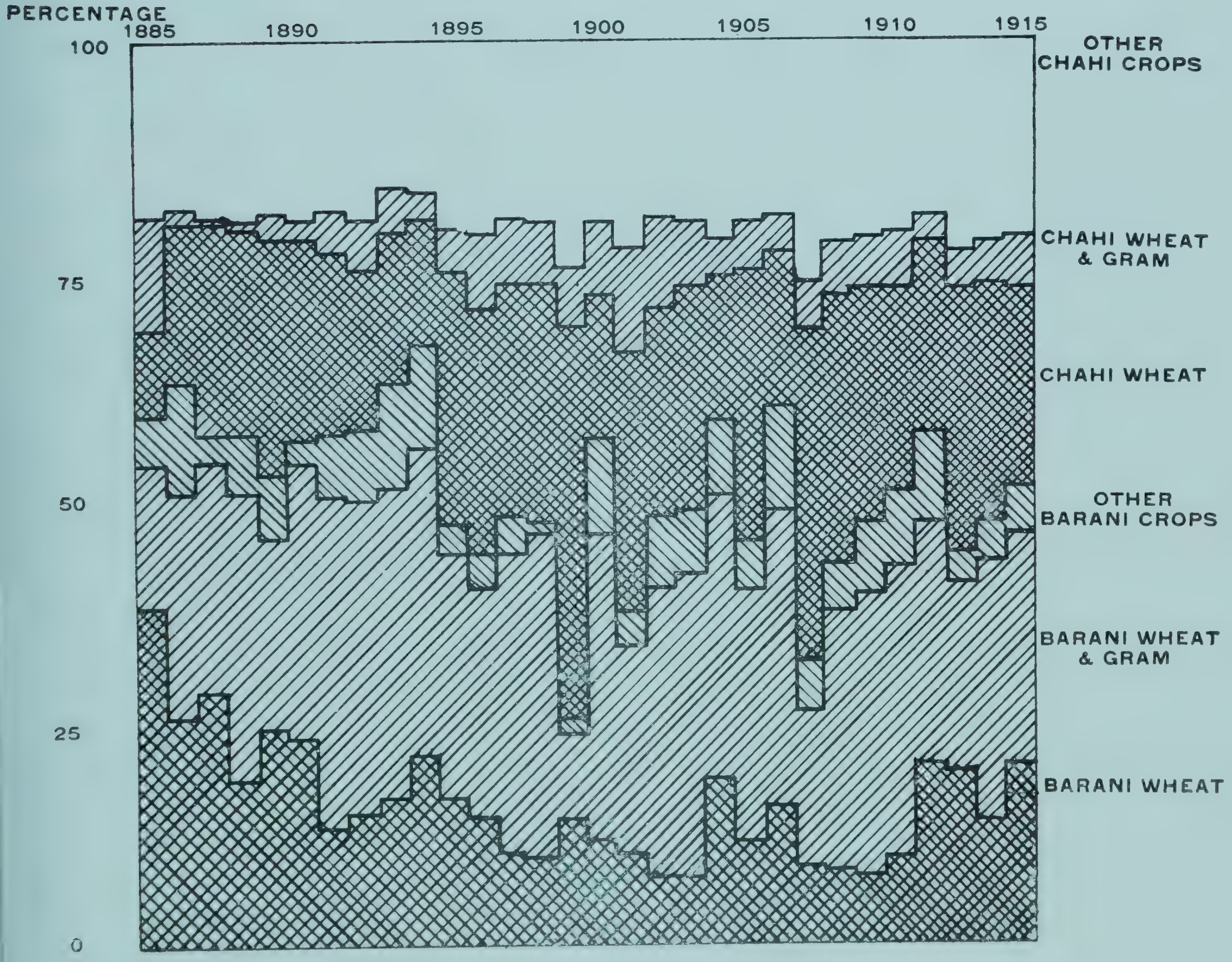
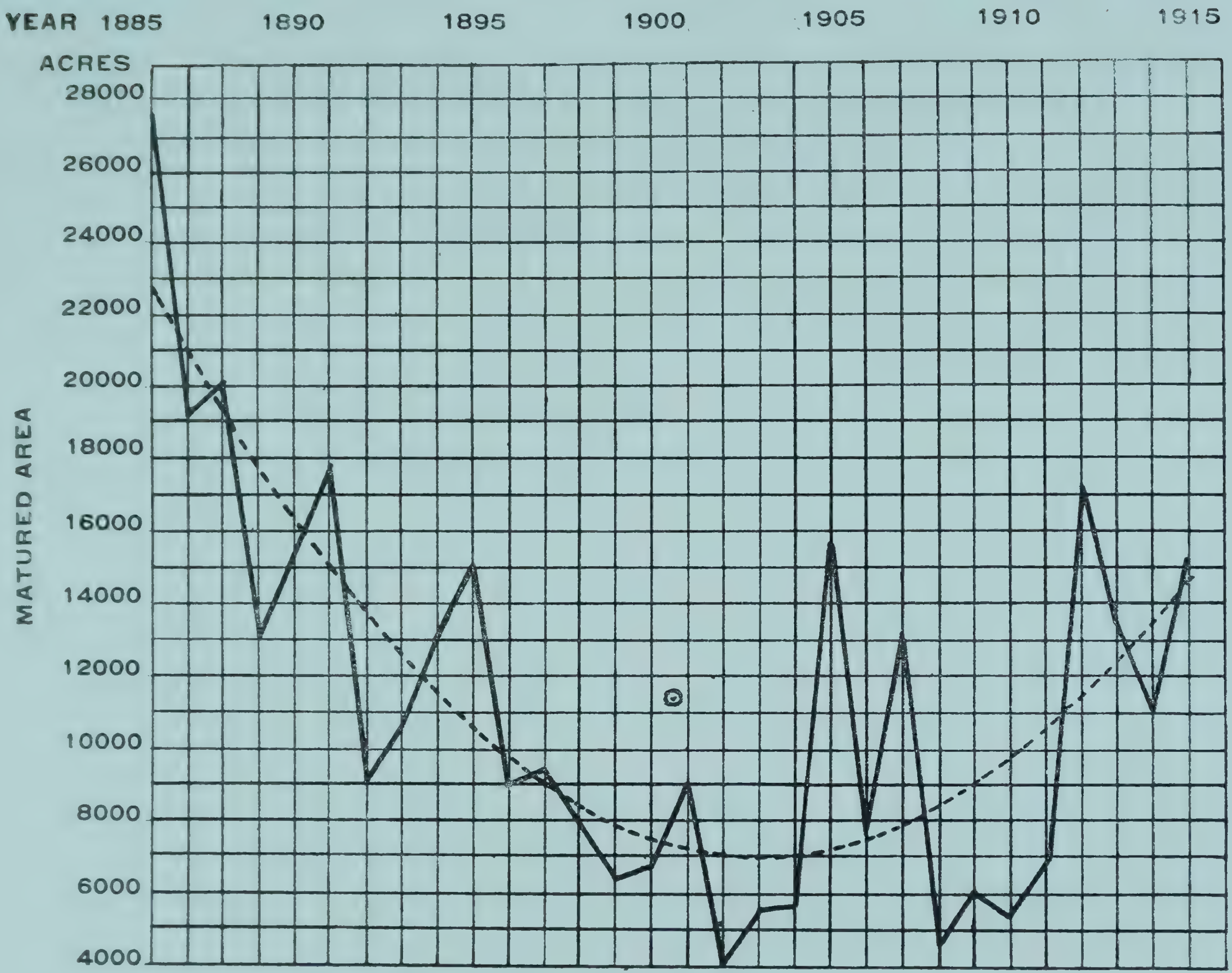


DIAGRAM VIII.

DONA CHARHDA CIRCLE JULLUNDUR TAHSIL

UNIRRIGATED WHEAT



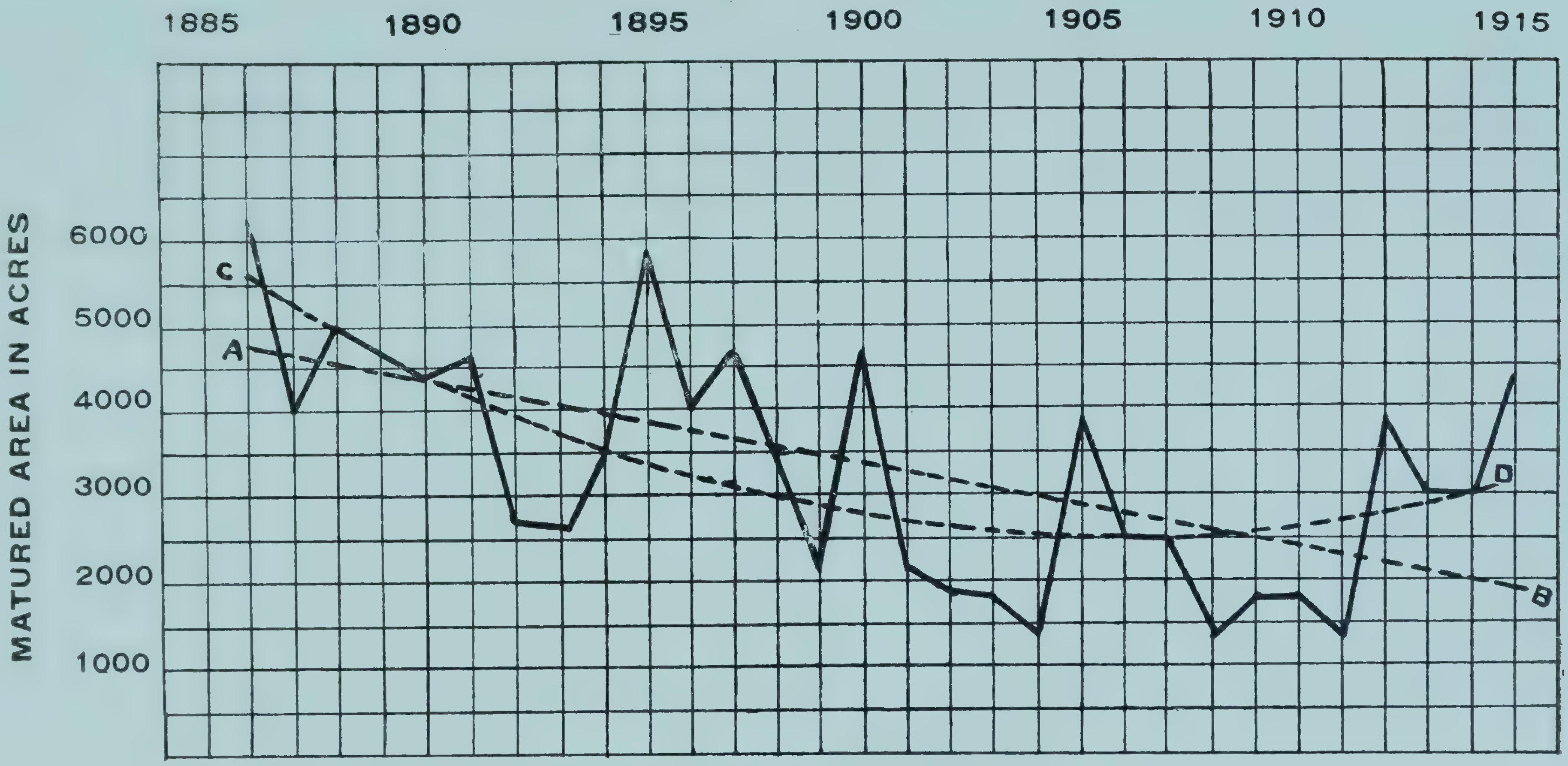
THE EQUATION OF THE PARABOLA OF CLOSEST FIT REFERRED TO THE CENTRE AS ORIGIN IS

$Y = -2{\cdot}01 - 0{\cdot}27X + 0{\cdot}108X^2$

DIAGRAM IX.

DONA LEHNDA CIRCLE JULLUNDUR TAHSIL

UNIRRIGATED WHEAT



AB IS THE STRAIGHT LINE OF CLOSEST FIT.
CD IS THE 2ND ORDER PARABOLA OF CLOSEST FIT.
THE EQUATION OF AB REFERRED TO CENTRE OF THE RANGE IS
$Y = -{\cdot}20\;2x$, AND OF CD. $Y = -{\cdot}56 - {\cdot}17x + {\cdot}03x^2$.
THE LINE OF CLOSEST FIT IS EQUIVALENT TO A DECREASE
OF 100 ACRES PER ANNUM.

DIAGRAM X.

SIRWAL BARANI WHEAT.

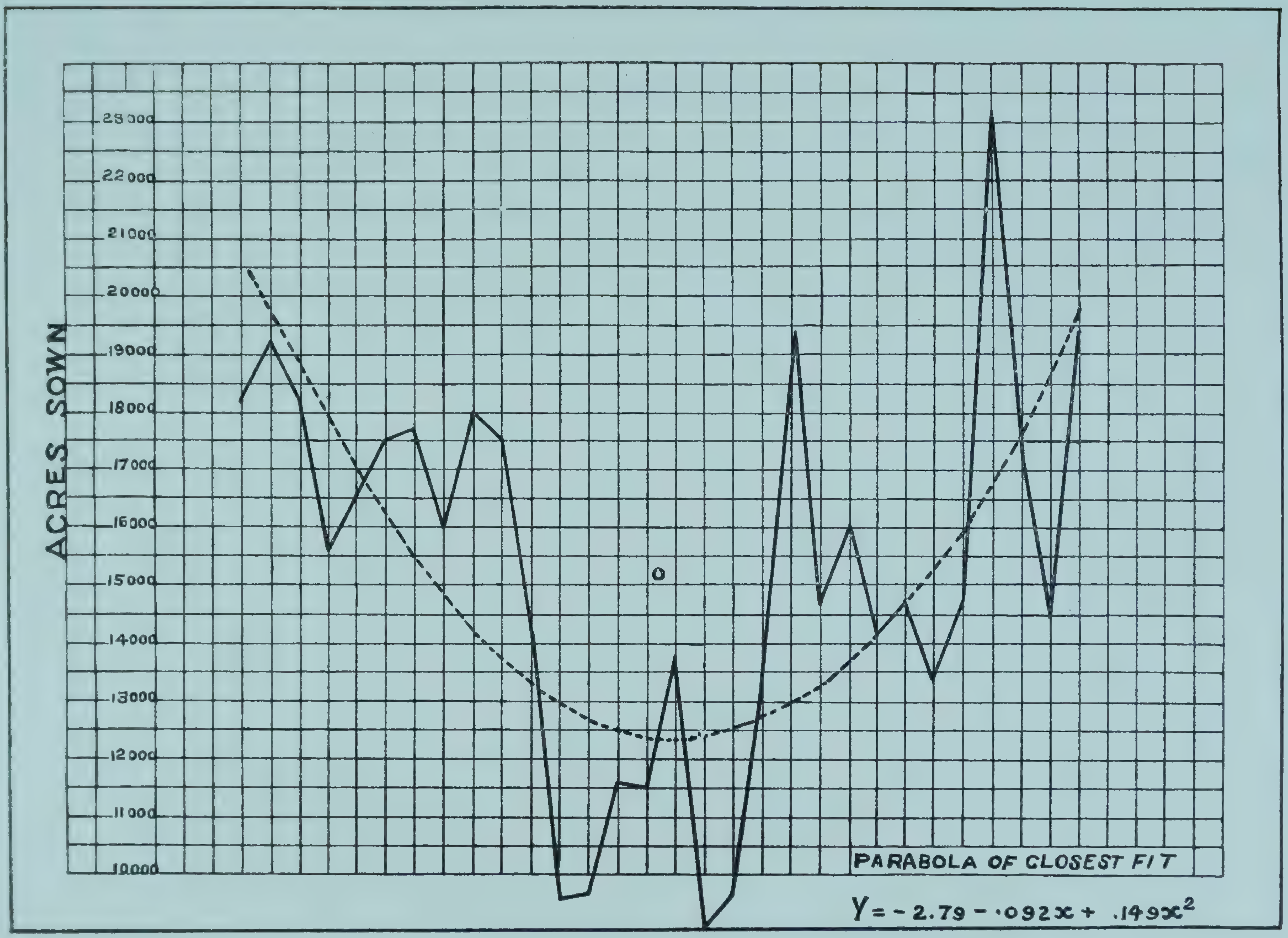
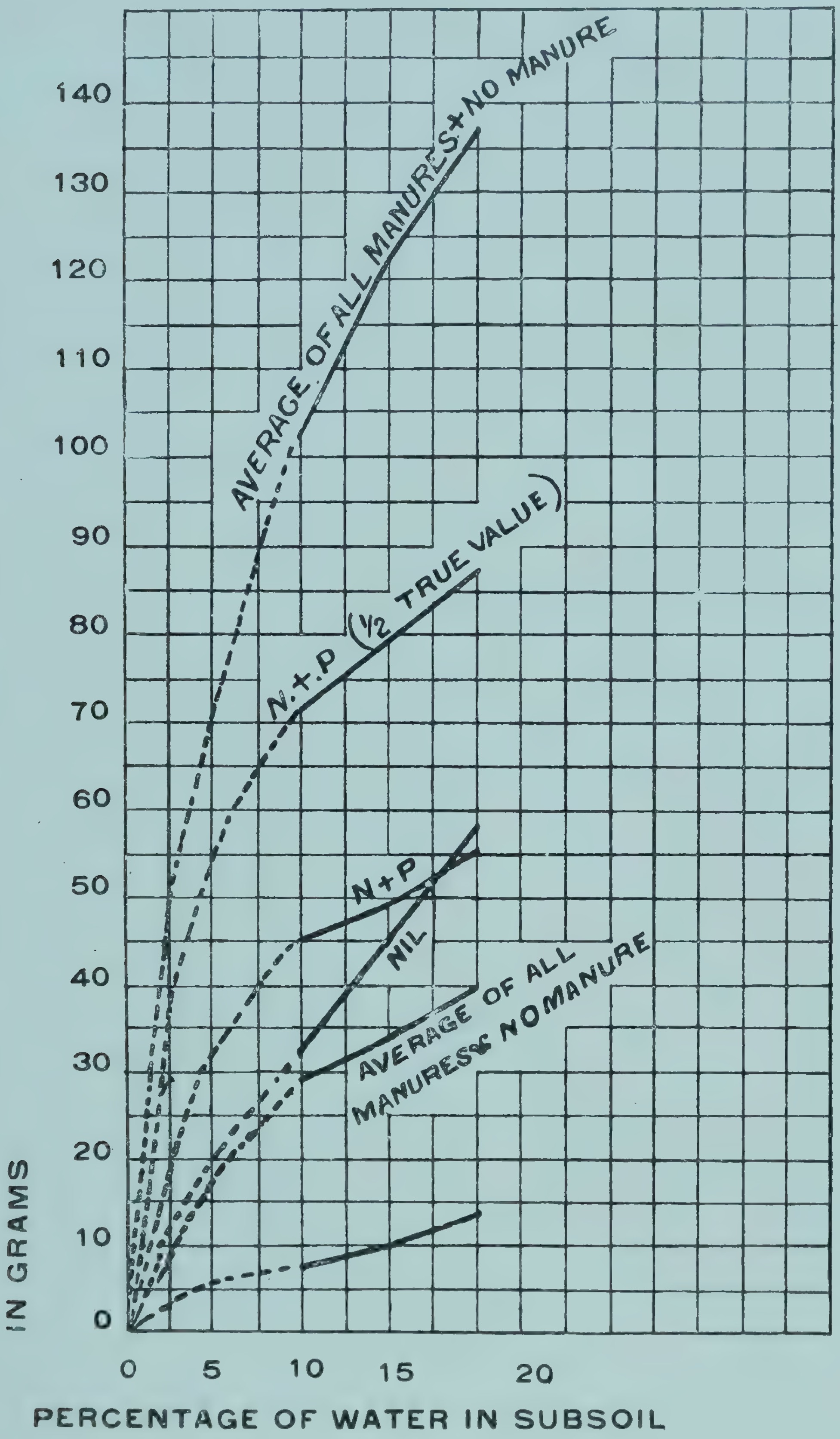


DIAGRAM XI.

EFFECT OF SOIL SATURATION ON YIELD OF WHEAT



N= CaCN2 P= SUPERPHOSPHATE

THE LOWER SOLID LINE IS THE AMOUNT OF SEED,

THE UPPER SOLID LINE IS THE TOTAL DRY CROP.

DOTTED LINES GIVE ASSUMED INTERPOLATIONS

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PREFACE.

THE Fifth Indian Science Congress met at Lahore in January 1918. The Agricultural Section was presided over by Dr. L. C. Coleman, Director of Agriculture, Mysore, and this special issue of the *Agricultural Journal of India* contains a selection of the papers bearing on agriculture and allied subjects read at the Congress. It is impossible to publish all the papers read on account of limitation of space.

The lecture by Messrs. Howard and Hole dealing with Recent Investigations on Soil-aeration will appear in the *Indian Forester*, and will also be published in subsequent numbers of the *Agricultural Journal of India* together with the following papers :—

(1) Some problems arising out of the successful introduction of American Cotton in the Western Punjab, by W. Roberts.

(2) Beginnings in insect physiology and their economic significance, by S. K. Sen.

(3) Coconut : The wealth of Travancore, by Dr. Kunjan Pillai.

(4) "Northerns" Cotton, by G. R. Hilson.

(5) Manures in their relation to soils and crop production in the Central Provinces, by D. Clouston.

(6) The improvement of "Tinnevellies" Cotton, by R. Thomas.

(7) The sun-drying of vegetables, by G. L. C. Howard.

The paper on Bacteriotoxins in Soils, by Mr. C. M. Hutchinson, will be issued as a Memoir ; while Mr. B. H. Wilsdon's paper on the Need and Objects of Soil Surveys in the Punjab and Mr. D. Milne's on the Improvement of Cotton in the Punjab will appear as Bulletins of this Department.

I am indebted to His Honour Sir Michael O'Dwyer, the Patron of the Congress, for his kindness in allowing his photograph to appear as frontispiece to this Number, while my acknowledgments are also due to the Asiatic Society of Bengal, under whose auspices the Indian Science Congress is held, for permission to publish the papers contained in this issue *in extenso*.

J. MACKENNA,

Agricultural Adviser to the Government of India.

PUSA :
May 12*th*, 1918.

CONTENTS.

PAGE

INDIAN AGRICULTURAL DEVELOPMENT ... *Leslie C. Coleman, M.A., Ph.D.* ... 1

IMMUNITY AND DISEASE IN PLANTS ... *E. J. Butler, M.B., F.L.S.* ... 10

THE ECONOMIC ASPECT OF INDIAN SILVICULTURE ... ... *Edward Marsden* ... 29

SOME METHODS SUITABLE FOR THE STUDY OF ROOT DEVELOPMENT ... ... *Albert Howard, C.I.E., M.A., and Gabrielle L. C. Howard, M.A.* ... 36

TIMBER SUPPLIES IN INDIA ... ... *R. S. Pearson, F.L.S.* 40

OXIDASES: WITH SPECIAL REFERENCE TO THEIR PRESENCE AND FUNCTION IN THE SUGARCANE *Ramji Narain, M.Sc.* 47

RHIZOCTONIA IN JUTE: THE INHIBITING EFFECT OF POTASH MANURING ... ... *R. S. Finlow, B.Sc., F.I.C.* .. 65

THE SPRAYING OF TEA IN NORTH-EAST INDIA *A. C. Tunstall, B.Sc.* 73

SOME FACTORS AFFECTING THE EFFICIENCY IN THE USE OF CANAL WATER ... ... *W. Roberts, B.Sc., and O. T. Faulkner, B.A.* ... 81

THE PHYSICAL TEXTURE OF SOILS IN ITS RELATION TO CROP PRODUCTION ... *D. Clouston, M.A., B.Sc., and A. R. Padmanabha Aiyer, B.A.* ... 89

FOREST GRAZING AND THE NELLORE "KANCHA" SYSTEM ... ... *Cecil E. C. Fischer* 95

SOME OBSERVATIONS ABOUT THE SOILS OF THE NORTH-EAST INDIAN TEA DISTRICTS ... *G. D. Hope, Ph.D., B.Sc., F.C.S.* ... 102

FOREST INSECT CONDITIONS IN INDIA ... *C. F. C. Beeson, M.A.* ... 114

EXPERIMENTS IN PLANTING SUGARCANE SETS WITH A SINGLE EYE-BUD AND POT EXPERIMENTS WITH OTHER SEEDS PLACED IN DIFFERENT POSITIONS WHILE PLANTING ... *M. L. Kulkarni* 125

LIST OF ILLUSTRATIONS.

Photo of His Honour Sir Michael Francis O'Dwyer, G.C.I.E., K.C.S.I. .. .. *Frontispiece.*

Facing Page

Plate I. Teak plantation in Burma, three years old, formed by sowing teak seed in combination with the cultivation of a catch-crop 29

Plate II. Teak plantation at Nilambur, Madras, age 65 years, nearly mature 30

Plate III. Fig. 1. Chir pine forest, closed to grazing, showing natural regeneration 32

Fig. 2. Chir pine forest, open to grazing, showing complete absence of natural seedlings.

Plate IV. Good natural regeneration of chir pine, showing seed-bearers being tapped for resin 33

Plate V. Plantation of *Bucklandia populnea*, 38 years old .. 34

Plate VI. Fig. 1. Sugarcane on *bhata* 91

Fig. 2. Groundnut grown on (*a*) *bhata*, (*b*) black soil.

Fig. 3. Indigo on *bhata*.

Fig. 4. Indigo on black soil.

Plate VII. Fig. 1. Cotton on *bhata* 92

Fig. 2. *Juar* on black soil.

Fig. 3. *Juar* on *bhata*.

Plate VIII. Fig. 1. Side view of the sugarcane rows grown with single eye-bud sets 126

Fig. 2. Front view of the sugarcane rows grown with single eye-bud sets.

Note.—There are also four diagrams illustrating Dr. G. D. Hope's paper on "Some observations about the soils of the North-East Indian Tea Districts."

HIS HONOUR SIR MICHAEL FRANCIS O'DWYER, G.C.I.E., K.C.S.I.,
Lieutenant-Governor of the Punjab.

INDIAN AGRICULTURAL DEVELOPMENT.*

BY

LESLIE C. COLEMAN, M.A., PH. D.,
Director of Agriculture in Mysore.

THE development of agriculture in India has formed the subject of an interesting and valuable report[1] by Mr. Mackenna which no doubt all of you have read. That report shows quite clearly that the Agricultural Departments in India have already justified the broad-minded policy inaugurated by Lord Curzon, through the increased returns which they have enabled and are enabling the Indian agriculturists to obtain from their land. It is, therefore, unnecessary for me to attempt an apologia for organized agricultural work in this country even were I competent to provide one. It might, however, be profitable for an unofficial scientific body such as the Indian Science Congress to examine the means which are being utilized to improve Indian agricultural conditions and to consider in how far those means are calculated to lead to permanent results. It would, I think, also be well within our province to point out certain dangers which lie ahead and to suggest means for avoiding them.

The two lines of work which appear to have yielded the most striking tangible results during the past ten years are :—

(1) The improvement of the staple crops of the country by selection and the organized distribution of the improved seed obtained ; and

---

* Presidential Address delivered before the Agricultural Section of the Indian Science Congress, Lahore, January, 1918.

[1] Mackenna, J. " Agriculture in India," 1915.

(2) the transfer of the best indigenous methods of cultivation and the best indigenous implements as utilized in certain areas to other more backward parts of the country.

The reasons why these two lines of work have produced tangible results so rapidly are fairly obvious. In the first place, neither demands on the part of the agriculturist an expenditure of money or labour greatly in excess of that which he has been accustomed to devote to the cultivation of his land. In the second place, neither requires, under the present conditions of low production which prevail in this country, very long or very accurate experimental work to enable agricultural experts to satisfy themselves as to the suitability of their introduction. The various Departments of Agriculture in India have been quick to appreciate these facts, and we find to-day in many provinces as much time and money being devoted to growing and distributing improved seed and to popularizing efficient indigenous agricultural practices and implements as on all the rest of the strictly agricultural work put together. I do not wish it to be thought that I consider plant-breeding as a kind of experimental work which requires less careful scientific control than others. I wish only to emphasize the fact that in a country such as India, where scientific work in connection with agriculture dates back hardly more than twenty years, improvement by selection is comparatively easy and plant-breeding work in India has up to the present been mainly confined to selection. Hybridization has been rarely resorted to. We have, it is true, the work of the Howards on wheat, Leake's work on cotton, and Barber's work on sugarcane, all of which are rich with promise for the future, but the improved varieties of crops which are being distributed on such a large scale in Madras, the Central Provinces, the United Provinces, the Punjab, and Bengal are, in practically all cases, the result of selection. As time goes on we shall no doubt find ourselves in the same position as the countries of Europe, when an immense amount of the most careful and painstaking scientific work will be required to evolve a type which is distinctly better than those already being grown, but we have not yet reached that stage of development.

As so much emphasis has been placed on plant-breeding during the past few years, it will be interesting to enquire just what are the probabilities of improvement in this direction. About eight years ago Dr. Hopkins of the Illinois Experiment Station sent a circular letter to various agricultural authorities in Europe, including such well-known men as Hall, von Seelhorst, Schneidewind, and Wagner, pointing out that, according to reliable statistics, the average yield of wheat and other cereals had increased in Europe by about 100 per cent. within the past century and enquiring what proportion of this increase could be attributed to each of the following four factors :—

(1) The use of improved seed.
(2) The use of plant food in commercial fertilizers and stable and green manures.
(3) Better rotation of crops.
(4) More thorough tillage.

The authorities consulted, while differing somewhat in their views, were practically agreed that the use of better seed had not provided more than 20 per cent. of the total increase in production. It will be interesting to compare with this estimate the results which have been obtained with certain crops in India. In parts of the Central Provinces, selected *roseum* cotton yields about 25 per cent. more than the mixture previously grown. Pusa 12 wheat gives an increase of from 10 to 25 per cent. in certain definite areas of the United Provinces, Bihar, and the Punjab, but unfortunately no very definite figures are available. The most striking results thus far obtained are perhaps those of Hector in Bengal, who has been able to isolate a strain of paddy yielding 30 per cent. more than the ordinary varieties grown by the ryot. From these examples, and I think they are fairly representative, it would appear that plant-breeding promises to do rather more for the Indian ryot than it has done for the European farmer. It is, however, pretty certain that this work alone will be of little permanent benefit unless it is accompanied by improvements along other lines. In fact it may be argued with a certain amount of plausibility that plant-breeding work by itself is, in many parts of India, likely to lead to permanent harm rather than to permanent good.

How, it may be asked, can such an opinion be supported? It is hardly necessary to repeat here the view which has been so frequently expressed that we have had in many parts of India for centuries a state of agricultural equilibrium. The soil is generally very poor, and the ryot uses on it very little manure. The crops he harvests are correspondingly low, and the varieties or mixtures of varieties which he grows are no doubt nicely adapted to the existing conditions. If we now isolate strains, which, in the first instance, yield us 20 per cent. or 30 per cent. more than the varieties or mixtures of varieties usually grown, this will result in an increased drain on the soil, and unless such a drain is counteracted by an increased return of plant foods to the soil we are likely to find, in a comparatively short time, the yield from these improved strains sink back to or below the level from which we started and to discover that the soil itself has been further impoverished. We are, no doubt, still too ignorant of the processes which are going on in the soils of India, and more especially of the biological factors which influence plant production, to speak with certainty on this point, but signs are not lacking that something similar to what I have foreshadowed is likely to occur. It should be noted, however, that the above remarks refer particularly to such crops as cereals and oil-seeds, where an increase in yield represents a definite increase in the plant food taken from the soil. In the case of such a crop as cotton, where increase in yield may result from an increase in ginning percentage, the amount of plant food removed from the soil should be approximately the same whether the old mixture or the improved strain is grown.

I do not wish to be understood from these remarks as intending to belittle the value to Indian agriculture of plant-breeding and the distribution of improved varieties. There is, however, a danger that the very striking results which have been obtained from this kind of work within the past ten years will make both scientific workers and the general public in India blind to the immense importance of other problems which face us, problems which, in many cases, will require the most patient and painstaking investigation by highly trained research workers for their solution. I shall return to this subject later and shall, in the meantime, turn to some of the other problems awaiting us.

The question of the conservation, improvement, and utilization of our manurial resources is a subject which has not received that amount of attention which it deserves. From the time of Voelcker onward we have had warnings with regard to the serious drain which the export of oil-seeds and bones has had upon our soils. The attention of the Board of Agriculture in India has been turned towards this question many times, but that body has not been able to reach any very satisfactory conclusions. Prohibition of export is a measure which seems too drastic and even the imposition of an export duty would be certain to meet with serious, if not insurmountable, opposition. The present, however, when a practical prohibition of export exists, is a most favourable opportunity for popularizing the use of these valuable products of Indian soils. We all trust that the conditions which have forced the present prohibition upon us will never recur, but it would, I submit, be almost criminal negligence on our part if we did not make the best use of the opportunity which it affords. The popularization of the use of oil-cakes as cattle foods and manures seems to me a matter of urgent importance. In this connection I may mention that an extensive campaign for the popularization of oil-cake as a manure for sugarcane is being organized in Mysore State, and, if the success already achieved can be taken as a guide, we should see within the next five or six years practically the whole of our oil-seeds being utilized for the improvement of our own soils. I anticipate that through manurial improvements alone an increase in our sugar yields of one hundred per cent. will be effected within the next ten years.

This, however, is only one of the manurial resources which have to be considered. The knowledge of our resources of mineral manures, more especially of phosphates, is very incomplete, nor has Government taken up seriously the question of exploring them thoroughly or of utilizing them to the best advantage. Finally, the question of the fixation of atmospheric nitrogen—a question which is engaging the attention of Europe, America, and Japan to an ever increasing extent—has scarcely been touched in India. Recently the Government of Mysore has taken up this question in connection with the development of the natural water power resources of the State, and there are prospects that a factory for the fixation of nitrogen on a fairly large scale will be started in the near future. The effect that a cheap and adequate supply of nitrogen would have on the returns from most of our staple crops is almost incalculable. Lastly we have the question of green manures, and we must confess, I think, that we have still a very long way to go before we can tell ryots how best to utilize these important improvers of soil fertility. The fact that at present, in some parts of India at least, more than fifty per cent. of the nitrogen content of the green manure is lost and thus never becomes available for soil improvement, indicates clearly enough what an important field of investigation we have here.

The question of the utilization of oil-seeds and other forms of commercial manures is, as has very frequently been pointed out, intimately bound up with the question of the amount of capital which the ryot has available. It is also closely connected with the education of the agricultural population, for a proper use of commercial manures presupposes a fairly high degree of intelligence.

As regards the question of capital, there is strong evidence that the condition of the Indian agriculturist has considerably improved during the past few years, and there is undoubtedly an increasing tendency for him to spend money on the cultivation of his land. This, we believe, is partly due to the efforts of the Agricultural Departments in India. That a demand for commercial fertilizers is beginning to arise among the ryots of India was an opinion generally accepted by the Board of Agriculture at their recent meeting in Poona. The influence of the co-operative movement is also increasing rapidly, and its effect upon the economic condition of the agriculturist during the next twenty years is bound to be enormous.

Turning to education, the demand for compulsory primary education is becoming more and more insistent. The number of schools in rural areas is increasing rapidly, and, provided our rural education is conducted on rational lines, it will lead to an awakening of the Indian agricultural population which is bound to have the most beneficent effect upon the development of our greatest industry. I have used the expression " on rational lines " with a purpose, for there seems to me the gravest danger that we shall, in India, commit the same mistakes which have been committed in other parts of the world and shall find the sons of our agriculturists leaving school with a distinct distaste for the occupation upon which the future prosperity of this country depends.

In the past, agricultural workers in India have been in the difficult position of having to justify their existence to two separate bodies. On the one hand, they have had to prove to an at-times-somewhat-critical Government not only that the work they were endeavouring to do was likely to lead to practical results commensurate with the money which was being expended upon it but also that the results obtained warranted the expenditure of very much larger sums of money. On the other hand, they have had to persuade a conservative agricultural population that improvements on existing methods were not beyond the bounds of possibility. Both these difficulties have been, to a most gratifying extent, surmounted, and signs are not wanting that ere long we shall be landed in the opposite difficulty of being over-powered with demands for a guidance which we are not able to furnish.

What do we require to fit us in the best possible way to meet the emergency which I have foreshadowed ? We need above all things a much larger and better organized research staff. Any one who has studied carefully the reports of the various Agricultural Departments, and more especially the reports of experimental farms, must realize that much of the experimental work which is being attempted is not likely to be of more than ephemeral value. This is more especially the case with regard to manurial experiments. All the experience of Europe goes to show that the most important increases in crop production have come as a result of the scientific use of manures. Germany is to-day able to feed herself largely because of her use of commercial fertilizers, and she has been taught how to use them to the best advantage through the immense amount of accurate experimental work which has been carried out on stations scattered all over the country. How much of this accurate experimental work do we find being done in India at present? Many of our experimental farms are scarcely worthy of the name because there is not sufficient scientific supervision and because there is, in too many cases, a demand that the farm shall show at the end of the year a favourable balance sheet. I am not prepared to assert categorically that an experimental farm which shows a profit stands thereby condemned of masquerading under a false name, but I am prepared to assert that if the time of the farm staff and the land on the farm are devoted, as they should be, to accurate experimental work, such a farm cannot be worked at a profit. The desire of the general public to see the results of experiments rather than the processes by which those results are obtained is a natural one. It should be satisfied by the only rational method, namely, demonstration on special farms or on the fields of cultivators. An experimental farm should be looked upon as an out-door laboratory, not as a model or demonstration. There may be room on it, as there is in a chemical laboratory, for rough qualitative tests, but to stop with these, as I fear too many of our farms have done in the past, is fatal to permanent progress. That we have not suffered more as a result of this foolishly economical policy is due to the fact that we have, for the most part, been dealing with fairly simple problems for which the approximate results obtained have furnished information upon which recommendations could be made with some degree of safety. As time goes on such approximate results will become steadily less useful, and unless we have substituted accurate experiments for the crude methods which now only too frequently obtain we may find ourselves in the unfortunate position of having to give to the ryot when he asks for bread, not a stone perhaps, but half-baked dough.

The question of research and experimental work is a pressing one. As I have already pointed out, the introduction of improved varieties is not likely to take us very far unless it is followed up by improvements in manuring and cultivation. An improved variety does, however, give the agriculturist an incentive towards better methods of treating his land, because it shows him that there are possibilities of increased profit from agriculture outside of those furnished by a rise of prices. The moment it becomes apparent that a crop will repay better soil treatment the question of just what treatment is soundest economically becomes one of the first importance. The questions which arise in connection with this subject are as many and varied as are the soils and climatic conditions of India, and require the most careful investigation not only at one or two special research institutes but also at a large number of experiment stations scattered all over this broad land and manned by thoroughly trained officers who are filled with a zeal for accurate scientific work. I strongly dissent from the view one sometimes hears expressed that observations in the field can in any way take the place of accurate experiment or that fewer precautions to avoid error are required in the case of agricultural than, for instance, chemical investigations.

In our work we are, I think, being tempted (I was about to say, being compelled) to confine ourselves to problems of the immediately practical character. This is no doubt largely due to the very small number of men engaged in agricultural investigations. It is also, I fear, partly due to our being afflicted to a certain degree with the shortsightedness which has landed the British Empire on the brink of disaster. If agricultural workers in India do not themselves insist upon the importance of fundamental investigation work even when such work does not hold out prospects of returns in the near future, we are hardly likely to find governments and the general public viewing such matters seriously. There was a time and not so many years ago when an insistence upon the importance of research might have been looked upon as a sort of lame excuse for failure to produce results of practical value. That time is, I think, past, and if we now fail to lay foundations deep and broad for the future development of agriculture in India we shall stand convicted by those who come after us of a criminal neglect of duty.

IMMUNITY AND DISEASE IN PLANTS.

BY

E. J. BUTLER, M.B., F.L.S.,

Imperial Mycologist.

Plants, like men, vary greatly in their liability to disease. Not only do we find, in both cases, individuals that can pass unharmed through epidemics, but still more often we find racial differences in susceptibility. It is quite common amongst plants for a race or variety to be much more resistant to attack by a given parasite than other races or varieties of the same plant.

Before considering more closely the circumstances which influence susceptibility to disease, it is necessary to define what is meant by immunity. By complete immunity is meant total resistance to infection. Such complete immunity to a parasite is rare amongst plants. We have a case in India in the cotton known as *buri*, which can be grown without loss of a single plant under conditions in which every plant of other varieties of cotton is killed by wilt, a disease prevalent in the Berars and caused by a hitherto undescribed fungus of the genus *Fusarium*, which lives in the soil. Much more common is relative immunity or relative resistance to infection, where the plant gets attacked by the parasite but the attack is mild as compared with that on less resistant kinds.

Even though a plant is not truly resistant, it may escape injury in other ways. It may avoid the parasite, or it may endure an attack without suffering material damage. We must therefore distinguish between the avoidance of disease, the endurance of disease, and true resistance to disease.[1]

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[1] Orton, W. A. "The development of disease-resistant varieties of plants." *IVe Conférence internationale de Génétique*, Paris, 1911, p. 249.

Plants may avoid disease in various ways. There are many parasites which are closely dependent on climate and seasonal conditions for their growth, and, with regard at any rate to our more common crops, it may be said to be a fairly general rule that cultivated plants are less closely dependent on such conditions than their parasites. Thus it is often possible to grow a crop under conditions which its parasites cannot stand, and we have many such cases in India. One was described by Dastur [1] in a paper presented at our last meeting, in which he pointed out that the common potato blight is unable to flourish in normal years on the plains of India, though endemic in the hills. Its temperature limits are too low for it to survive the heat of the plains, unless introduced from the hills after the beginning of the cold weather, an event that seems to have only occurred two or three times in the last twenty years. Even when thus introduced, it is only able to damage a single season's crop, and is then killed out by the following hot weather. Another case is the smut of *jowar* (*A. Sorghum*), caused by *Sphacelotheca Sorghi*, which ranks as one of the worst diseases of crops in India, causing a loss of probably more than a million sterling every year in Bombay alone. This disease is rare in the Gangetic Plain, owing to the fact that the temperature is too high in that area to permit its spores to germinate at sowing time. The spores are carried on the grain and infect the young seedling within a few days of germination. Experiments at Pusa and Poona show that the spores germinate best between 70° and 80°F., which is lower than the normal temperature at sowing time in the Gangetic Plain. Then there are several diseases found only in the north-west of India, though the crops attacked extend through a large part of the country. One is bunt of wheat, which is extremely destructive in Kashmir and is found in the western and submontane Punjab, but not elsewhere in India. Its spores germinate best at 60° to 65°F., which is below ordinary sowing temperatures for wheat in all but the extreme north-west. Another somewhat different case of disease avoidance is found in groundnut. This crop suffers severely from a disease called *tikka* in Bombay, caused by the fungus *Cercospora personata*. The parasite attacks the leaves and stalks, and prevents the nuts from maturing properly by causing premature loss of leaf. It appears usually a month or more after the break of the monsoon and is at its height by September. The Bombay Agricultural Department introduced early-maturing varieties of groundnut with the result that, though they got the disease, their nuts were well advanced at the time and suffered relatively little. The export of groundnut from Bombay fell from nearly 80,000 tons in 1894 to less than 3,000 tons in 1902 when the disease was at its worst, but rose again after the introduction of the new varieties reaching to nearly 50,000 tons in 1912. In several similar cases it is possible to avoid a disease by altering the date of sowing. But it is clear that there is no question of any real resistance inherent in the plant in all these cases. The plant dodges the attack and that is all.

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[1] Dastur, J. F. "Conditions influencing the distribution of potato blight in India." *Agric. Journ. India*, Special Science Congress Number, 1917.

Plants may endure disease owing to a high degree of vigour. When an epidemic breaks out in a crop, every plant is usually exposed to repeated infection, and naturally the weakly plants are liable to be more injured at first than those that were growing luxuriantly at the time of attack. The coffee leaf disease, which destroyed the industry in Ceylon, broke out first about fifty years ago in some of the best coffee in the Island. It has actually been proved to grow better on strong plants, rich in nutriment, than on weakly bushes. Yet the latter are far more injured by it, for they are unable rapidly to put out new leaves to replace those killed by the fungus. The attack is confined to a few months of the year, and a bush with plenty of reserve vigour is able in great part to restore the loss of leaf and meet a fresh attack next season with its vitality but little impaired. A weak bush cannot do so, and each successive attack appreciably reduces its strength and it may finally succumb.[1] Hence the disease is habitually fought by increasing the vigour of the bushes by heavy manuring and improved cultivation.

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[1] Faber, F. C. v. "Die Krankheiten und Schädlinge des Kaffees." *Bakt. Centralb.*, 2nd Ab., XXI, 1908, p. 106.

In other cases, plants are able to endure a parasitic attack because their tissues are able to react so as to lessen the injury, and the more vigorous the plant is, the more rapid and complete the protective reaction will be. In the red rust of tea (*Cephaleuros Mycoidea*), for instance, the chief damage is due to attacks on the young twigs, which are eaten into by the parasite working from the surface in towards the wood. Corky bark cannot be penetrated, and as soon as the attack develops, the plant endeavours to stop it by laying down cork under the point of infection. A vigorously-growing bush can often do this successfully, but in neglected gardens, or where there is a stiff subsoil which interferes with root development, the parasite penetrates more rapidly than cork can be formed, and the twig is killed.[1] Since measures have been taken to improve the vigour of the bushes by drainage and attention to soil conditions, the disease, which formerly was regarded as probably the worst tea disease in certain districts, has lost much of its terrors. Of course it must not be understood that all parasites behave in this way. There are many that can injure strong as easily as weak plants, like potato blight, or are even more severe on the stronger plants, as many of the mildews which refuse to grow at all on plants whose leaves are yellowing, or infected with aphis, or otherwise not in a flourishing condition.[2]

We now come to true disease resistance. After excluding the above easily understandable cases, there still remains a large number in which the plant actually refuses to allow the parasite to grow on it, or only permits it to do so in a grudging manner. True disease resistance of this nature must depend on either anatomical or physiological characters of the host plant, and the latter are by far the more important.

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[1] Mann, H. H., & Hutchinson, C. M. "*Cephaleuros virescens*, Kunze: the red rust of tea." *Mem. Dept. Agric. India, Bot. Ser.*, I., No. 6, 1907.

[2] Reed, G. M. "Infection experiments with *Erysiphe Cichoracearum* DC." *Bul. Wisc. Univ.*, No. 250, 1907. Melhus, I. E. "Experiments on spore germination and infection in certain species of *Oomycetes*." *Wisc. Agri. Expt. Sta. Res. Bul.* 15, 1911.

It is necessary at this stage to consider a little more closely what is meant by infection. When a parasite attacks a plant we are able often to distinguish two stages in the process. The first is the stage of penetration, that is the actual entry of the parasite into the tissues. The second is the establishment of parasitic relations between the parasite and its host, which means really the obtaining of suitable food for its development from the tissues of its host. It is perfectly possible for a parasite to force an entry into a plant on which it is unable to feed and consequently to grow. Some of the rusts, for instance, will enter all sorts of plants, but once inside, they die, unless they happen to be on the plant which they ordinarily inhabit.[1] From the other plants they are unable to obtain food of the sort required for their growth, or else meet with some barrier inimical to their growth. The wheat mildew (*Erysiphe graminis*) will germinate on a leaf of barley, and will even force a sucker into the outer layer of leaf cells just as it does on a wheat leaf. But whereas in the wheat cell the sucker remains turgid and absorbs enough food to enable the parasite to continue its growth and form new suckers, on barley, under ordinary circumstances, it cannot get suitable food from the cell, and it shrivels and dies.[2]

It is frequently the case that immunity due to anatomical characters of the host plant depends on conditions which prevent the first stage of infection, namely, penetration, while immunity which is due to physiological characters depends on conditions which do not interfere with penetration but prevent the second stage of infection, the setting up of parasitic relations between the fungus and its host.

Most of the cases where immunity depends on anatomical characters are thus connected with the condition of the surface layers of the plants. For instance, there are many fungi which can only enter a plant through the breathing pores or stomata of green parts, and the chances of a plant escaping infection by one of these will be influenced by the number and other characters of the stomata. Coffee leaf disease usually starts on the under surface of the leaf, as there are few stomata on the upper surface. In this case, infection generally occurs while the leaf is turned over by the wind, or is still partly folded in the bud with its under surface turned outwards so as to be easily reached by spores deposited from the air. Sometimes the size of the stomata is important, as in the beet leaf spot caused by *Cercospora beticola.* Immature beet leaves are practically immune, because their stomata are small and incapable of opening widely enough to admit the germ-tubes of spores germinating on their surface.[1] Certain varieties of plums have been shown to be resistant to brown rot caused by *Sclerotinia cinerea,* because the stomata early become plugged with masses of small parenchymatous cells. In the more susceptible varieties, penetration through the stomata is not impeded in this manner.[2]

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[1] Gibson, Miss C. M. "Notes on infection experiments with various *Uredineæ*." *New Phytologist*, III, 1904.

[2] Salmon, E. S. "On the stages of development reached by certain biologic forms of *Erysiphe* in cases of non-infection." *New Phytologist*, IV, 1905.

In a few cases, the surface of a plant is not easily wetted, and fungi that depend on the deposit of films of water on the green parts for their germination may fail to secure a footing. Thus it has been noticed that the more waxy varieties of raspberries and grapes are least damaged by *Coniothyrium,*[3] and that barley in which the amount of bloom has been increased by growth in alkali soils may have its resistance to rust heightened.[4]

The number of hairs on a leaf may also influence resistance to attack. Potatoes with small, hairy leaves and an open habit of growth dry quickly after wetting and are less liable to blight than other kinds.[5] Hairs also seem to save the under surface of apple leaves from infection with the scab fungus, *Venturia inæqualis,* while the allied *Venturia pirina* readily attacks the smooth under surface of pear leaves.[1] The very hairy leaves often found in buds are sometimes noticeably immune to fungus attack.

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[1] Pool, V. W., & McKay, M. B. "Relation of stomatal movement to infection by *Cercospora beticola.*" *Journ. Agric. Res.*, V, 1916.

[2] Valleau, W. D. "Varietal resistance of plums to brown-rot." *Journ. Agric. Res.*, IV, 1915.

[3] Appel, O. "Disease resistance in plants." *Science*, n. s., XLI, 1915. Istvanffi, G. v. "Études sur le rot-livide de la vigne." *Ann. Inst. Centr. Ampélo. Roy. Hongrois*, II, 1902.

[4] Freeman, E. M. "Resistance and immunity in plant diseases." *Phytopathology*, I, 1911.

[5] Appel. *l.c.*

In a few cases, structural or morphological peculiarities of a variety are of considerable importance in connection with liability to disease. Thus wheats with very open glumes are more liable to loose smut, *Ustilago Tritici*, a fungus that infects through the flower, than those of a close habit. In some varieties of pears an open channel is left from the calyx to the carpels, and these varieties suffer much from the attack of *Fusarium putrefaciens*, a fruit-rotting organism.[2]

With regard to the inner tissues of plants, which the parasite only reaches after penetration has been successfully accomplished, structural characters occasionally take part in checking an attack. Thus in several of the cereal smuts, infection may be successful up to a point but ultimately fails unless the parasite reaches the growing point of the seedling within a limited period of time, which seems to vary with different varieties of the crop. The hyphæ can only penetrate the tissues while these are still young and undifferentiated, and they may be trapped in the lower part of the primary shoot unless they get past the primary node before its vascular tissue develops. When thus trapped they soon die.[3] There are many other cases in which age influences the receptivity of the tissues, and though some of these are doubtless physiological and depend on the characters of the living parts of the cells, others probably depend on the nature of the non-living walls and are therefore anatomical. For instance, plums often get increasingly liable to brown rot as they ripen, owing to a natural softening of the middle lamella between the cells, which enables the parasite to force its way through the tissues more rapidly than before softening takes place.[4] It must not be forgotten that parasitism in fungi is in its essence an enzymic activity : the fungus usually dissolves its way through the tissues by means of enzymes produced from the tips of its threads; and since these enzymes vary from fungus to fungus and usually act each on only a single type of wall, it is evident that the successful growth of the fungus may be greatly affected by the characters of the walls of the host cells.

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[1] Ducomet, V. "Recherches sur le développement de quelques champignons parasites à thalle subcuticulaire." Thesis, Paris, 1907.

[2] Appel. *l.c.*

[3] Lang, W. "Zum Parasitismus der Brandpilze." *Jahresber. Verein. f. angew. Bot.*, X, 1913.

[4] Valleau. *l.c.*

External conditions sometimes modify the anatomical characters which influence the resistance of a plant to disease. It has already been mentioned that the amount of bloom on barley leaves may be raised by growing in alkali soil, with an accompanying decrease in damage by rust. In pink disease of rubber, caused by *Corticium salmonicolor*, the attack is often most marked on the shady side of the trees, and it seems probable that the thinner cork of shaded parts offers a lesser resistance to penetration. Both moisture and shade affect the tissues in a somewhat similar manner, leading to fewer hairs, a thinner cuticle, and relatively less sclerenchyma, so that the increased susceptibility of densely growing crops is probably in part due to the greater ease with which their tissues can be penetrated. But it must not be forgotten that such conditions also modify the cell contents, and the thin walls of etiolated plants are due to physiological changes which modify metabolism and are accompanied by a diminution in sugars, protein, and volatile oils in the cells.[1] Hence the loss of resistance may be in part due to physiological causes, and the more we examine such cases, the more important becomes the physiological side of the question.

So far we have considered some of the circumstances which help a plant to avoid attack by a parasite, those which enable it to endure a successful attack, and those anatomical characters which produce a true resistance to attack. All of them are fairly easy to understand, and it is generally possible to specify the character concerned and to see clearly how it acts. There remains the consideration of the physiological characters of a plant which affect its resistance to parasitic attack. These are much more obscure and are the least understood as well as certainly the most important of the factors controlling immunity. They depend, so far as we know, entirely on the nature of the cell contents, and are independent of the anatomical structure of the plant or the nature of its cell walls.

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[1] Duggar, B. M. "Physiological plant pathology." *Phytopathology*, I, 1911.

A few instances which will establish the existence of this class of factors may be given. I have already mentioned that barley leaves are ordinarily immune to the attack of the mildew, *Erysiphe graminis*, from wheat. But the immunity can be broken down by immersing the leaf in warm water, touching it with a hot knife, exposing it to the vapour of ether, chloroform, or alcohol, and in other ways.[1] Maize smut (*Ustilago Zeæ*) is confined normally to those parts of the plant where the cells are young and still capable of division. But by exposing the plant to the vapour of ether, or heating it to 70°C., much more extensive infection can be obtained.[2] Again it is possible to check the growth of the cereal rust fungi even after they have become well established in the tissues, by modifying the nutrition of the plant. Cutting off infected leaves, starving the plant by reducing the supply of carbon-dioxide or mineral salts, or heating or cooling the roots, will check an attack.[3] It is obvious that exposure to ether vapour or temporary starvation cannot rapidly modify the anatomical structure, and the change in resisting power must be due to some alteration in the cell contents.

What are the cell contents which are of importance in immunity? In the first place, they may be the living substance, the protoplasm itself. We know that it is of the utmost significance to many fungi whether the organic food offered to them is living or dead. The whole of the saprophytic fungi require their food to be dead before they can utilize it. On the other hand there are large groups of parasitic fungi that, so far as we know, cannot make any use of dead food. Not a single one of the rust fungi, of which there are several thousands of species known, has ever been cultivated on artificially prepared food, and the same is true of many other species. Now it has been actually proved that the immunity of certain plants to some of their parasites is really due to hypersensitiveness. The parasite attacks the first cells it reaches too vigorously, kills them, and is soon surrounded by a ring of dead cells beyond which it cannot pass. In the non-immune sorts it enters the cells and only takes a certain amount of food from them, without killing them, before it has had time to grow on and reach fresh living cells. This sequence of events has been observed in the rusts and in the *Venturia* scabs of apple and pear.[1] In other cases it seems that there is some quality of the protoplasm which impedes the growth of the fungus, and it is this quality, whatever it may be, that is destroyed by ether and the other substances or conditions mentioned above as lowering the resistance of immune plants. What these qualities of the protoplasm are is not known, nor whether there exists in plants anything approaching the antibodies found in the blood of animals and man, which can impede the growth of a parasite.

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[1] Salmon, E. S. "Further cultural experiments with 'Biologic Forms' of the *Erysiphaceæ*." *Ann. of Bot.*, XIX, 1905.

[2] Ray, J. "Etude biologique sur le parasitisme : *Ustilago Maydis*." *Comptes rendus*, 136, 1903, p. 567.

[3] Ward, H. M. "Recent researches on the parasitism of fungi." *Ann. of Bot.*, XIX, 1905.

Then there are the non-living parts of the cell contents, substances which for the most part occur dissolved in water to form the cell sap. Of these, two seem to be specially important from our point of view : tannin, and organic acids such as tartaric, malic, citric, and the like.

Tannin is of very frequent occurrence in vegetable cells. Very occasionally it can be used as food by fungi, but as a rule it is distinctly toxic to them, and this toxic action is in general more marked on parasites than on saprophytes. The mechanism by which plants seem to make use of the toxicity of tannin in resisting fungus attacks is somewhat complex. In the living cell, in some cases at least, there is formed first an enzyme, which acts on gallic acid pre-existing in the cell, to form tannin or a tannin-like body equally toxic. The power of producing this enzyme varies at different stages of growth. In beans, for instance, the enzyme decreases from the seedling stage until the flower buds form when it increases, then decreases again as the fruits set, rises as the latter reach full size, and finally falls as they ripen off. Now in the bean these variations correspond with the susceptibility to the disease called anthracnose, caused by *Colletotrichum Lindemuthianum.* So also in many fruits (apples, pears, persimmons, etc.) the enzyme is less in the ripe than in the green stage, and all these fruits are notoriously liable to various ripe rots which develop at full maturity but are rare on unripe fruit. In all cases the fungus is readily inhibited in its growth by tannin, and the susceptibility to ripe rots has been found to vary inversely with the power of the plant to form the oxidase which starts the toxic reaction.[1]

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[1] Ward, *l. c.* Stakman. "Relations between *Puccinia graminis* and plants highly resistant to its attack." *Journ. Agric. Res.*, IV, 1915. Wiltshire, S. P. "Infection and immunity studies on the apple and pear scab fungi (*Venturia inæqualis* and *V. pirina*)" *Ann. Applied Biology*, I, 1915.

As regards organic acids, the evidence indicates that resistance to disease in many cases is due to a greater acidity of the cell sap, but in a few to a lesser, as compared with non-resistant varieties of the host plant. In the black rot of the grape-vine, caused by *Guignardia Bidwellii*, the resistance of certain varieties and parts of the vine has been correlated with the lesser amount of tartaric acid contained in their sap as compared with non-resistant varieties or parts. Those varieties that are rich in acid and form sugars late, as the "Folle blanche," are less resistant than those with little acid and early sugar-formation, like the "Clairette." It is known also that the leaves are only susceptible while they are young and rich in tartaric acid, while as they mature the acid diminishes and they become immune. In the same way the fully ripe grapes, which have lost most of their acid, are not susceptible. The fungus has been grown in culture and found to prefer an acid medium, being arrested by alkalis and retarded by sugars.[2]

In the grey rot of the vine, caused by *Botrytis cinerea,* the opposite is the case, as here it has been noted that the best preventive is to grow those varieties that give an acid must, like the Italian "Raboso di Piano."[1] It has been established that this fungus is repelled by certain acids found in plants.[2]

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[1] Cook, M. T., & Taubenhaus, J. J. "The relation of parasitic fungi to the contents of the cells of the host plants." *Delaware Agric. Expt. Stat. Buls.* 91 and 97, 1911-12.

[2] Viala, P., & Pacottet, P. "Sur la culture du black rot." *Comptes rendus,* 138, 1904, p. 306.

The resistance of vines to oidium and mildew has also been correlated with the acidity of the cell sap. The average acidity of leaves and must of the more resistant kinds tested (expressed in terms of tartaric acid) was from 3 to 5 times that of the non-resistant varieties.[3]

It has also been observed that the branches of lemon attacked by gummosis contain less acid than those of healthy plants, and that the less acid lemon fruits stand long journeys badly, being more readily attacked by rotting organisms than the highly acid kinds.[4]

The resistance to parasites of the hard wheats (macaroni, rivet, spelt, and Polish) is generally higher than that of common wheat. In these kinds there is relatively more glutin and less starch, more organic acid and less sugar in the sap.[5] In Italy, a wheat strongly resistant to rust known as Rieti has been examined in some detail. It has been found to have a more acid sap than that of any of the other, less resistant, kinds tested under the same conditions. Furthermore this wheat loses its resistance to some extent when grown in warmer localities than its native area, and this loss of resistance is accompanied by reduced acidity of the sap.[6] Wheat rust has never been cultivated artificially, as previously mentioned, so that its behaviour to acids is not directly known, but another wheat parasite, *Leptosphæria herpotrichoides*, is known to require an alkaline reaction in culture and to be arrested by acids.[7]

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[1] Sannino, quoted in Comes, O. "Della resistenza dei Frumenti alle Ruggini." *Ann. R. Scuola Agric. di Portici*, XII, 1914, p. 455.

[2] Massee, G. "On the origin of parasitism in fungi." *Phil. Trans. Roy. Soc.*, B, 197, 1904.

[3] Averna-Sacca, R. "L'acidita dei succhi delle piante in rapporto alla resistenza contro gli attacchi dei parassiti." *Stat. Sper. Agrar. Ital.*, XLIII, 1910.

[4] Comes. *l. c.* pp. 435 and 450.

[5] *ib.* p. 451.

[6] *ib.* p. 466.

[7] Fron, G. "Contributions à l'étude de la maladie du pied noir des céréales." *Ann. Sci. Agron. Française et Etrangére*, 4e Ser., I, 1912.

In general, the cultivated varieties of a plant are more susceptible to parasites than the wild stock from which they originated. This is noticeably the case in fruit trees, and in these the wild sorts are practically always richer in acid than the cultivated. In sugarcane too the thin canes of northern India, which are the most nearly related to the wild Saccharums, are relatively immune to certain parasites of the pith, but whether this is connected with higher acidity of the juice is not clear.

That there are other cell contents of importance besides those mentioned is probable. Sugar has been often suspected of a considerable influence, but as it usually varies inversely with the acid content it is possible that the latter is really concerned. Thus I have shown that the red rot fungus, *Colletotrichum falcatum,* is present in infected canes from sowing time but usually only develops severely as the cane matures. I attributed this to the increase in sugar, but it may equally well be due to a decrease in acid.[1]

In some cases neither tannin nor organic acids influence immunity. In potato tubers resistance to *Phytophthora infestans* is a property of the living tissues, but attempts to connect it with the reaction of the cell juices or the tannin content have failed.[2]

It will be seen that the direct proof that resistance to disease depends on single constituents such as tannin or acids is still wanting. The evidence given above is mostly circumstantial. This is partly due to the intrinsic difficulty of estimating accurately small differences in the composition of the cell contents, and also probably to the processes concerned being complex as in the case of the tannin-formation mentioned above. That the changes concerned are subtle is evident, since it is known that resistance to one disease does not imply resistance to another,[3] that different parts (such as the leaves and tubers of potatoes) may vary in their resistance,[4] and that physiological resistance can be affected by a large number of external conditions.

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[1] Butler, E. J. "Fungus diseases of sugarcane in Bengal." *Mem. Dept. Agric. India, Bot. Ser.,* I, No. 3, 1906.

[2] Jones, L. R., Giddings, N. J., & Lutman, B. F. "Investigations on the potato fungus : *Phytophthora infestans.*" *U. S. Dept. Agric., Bur. Pl. Indus. Bul.* 245, 1912.

[3] Orton. *l. c.*

[4] Jones, Giddings, & Lutman. *l. c.*

Amongst the latter, climate, soil, nutrition, and the like, have been shown sometimes to have a marked influence.

It is fully established that immunity in one locality does not necessarily mean immunity to the same disease in another locality. In India it has been found that wheat resistant to rust in one place, may be attacked in another. At the famous wheat-breeding station, Svalöf, in Sweden, several introduced varieties were badly attacked, though almost immune under other conditions.[1] So also in South Africa, an Australian rust-resisting wheat remained exceptionally immune at Pretoria, but was much damaged in the low country.[2] In the United States a wilt-resisting watermelon lost its resistance as it was moved west towards the Pacific coast.[3]

Soil conditions also have sometimes a marked effect. Alder trees in Germany suffer more severely from the parasite, *Valsa oxystoma*, when growing in meadow land than in the swampy soil which they prefer.[4] Larch canker is worst on calcareous soils and rare on siliceous.[5] So also the oidium and mildew of the vine are said to be more prevalent on soil rich in lime than in sandy loam, because the acidity of the sap is reduced by the former,[6] and several other cases are known where an excess of lime predisposes to disease. On the other hand, those varieties of Iris that prefer a limestone soil are liable to be severely attacked by *Heterosporium gracile* when grown in soil deficient in lime.[7]

As regards nutrition, there is a great deal of evidence that resistance to disease can be materially affected by the amount and quality of the plant food supplied. Thus in a paper which will be read at this meeting,[1] Mr. Finlow has shown that the resistance of jute to *Rhizoctonia* can be much increased at Dacca by manuring with water-hyacinth ash, a substance rich in potash. I also have observed that complete immunity to this disease can be induced by exceptionally heavy doses of mixed manures, but the particular ingredient concerned, whether potash or something else, was not recognizable. At Pusa, on the other hand, the no-manure plots of the permanent experiment series are relatively free from *rahar* (*Cajanus indicus*) wilt, caused by *Fusarium udum*, as compared with some of the manured plots. The figures this year, for instance, are :—

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[1] Nilsson-Ehle, H. "Kreuzungsuntersuchungen an Hafer und Weizen, II." *Lands. Univ. Arrskrift*, 2nd Af., VII, 1911.

[2] Pole Evans, J. B. "South African cereal rusts." *Journ. Agric. Science*, IV, 1911.

[3] Orton. *l. c.*

[4] Appel, O. "Ueber bestandweises Absterben von Roterlen." *Naturw. Zeit. f. Land-u. Forstwirt.*, II.

[5] Ducomet, V. "Pathologie végétale," p. 62.

[6] Averna-Sacca. *l. c.*

[7] Ramsbottom, J. "Iris Leaf-blotch." *Journ. R. Hort. Soc.*, XL, 1914-15.

Manurial Series.

No-manure plot: deaths up to 20th December, 1917	**12**
The three superphosphated plots respectively	**1035, 1194, & 1451**

and by the end of the season I anticipate that nearly half the crop in these last plots will have been destroyed.

Both these last cases are diseases caused by soil parasites. It is arguable that the manure has acted rather by affecting the growth of the parasite than by altering the true resistance of the plant. This aspect of the question is now under investigation, and in any case it cannot be called in to account for most of the following, as they refer to parasites of the above-ground parts of the plant.

At Rothamsted, where permanent manurial experiments have been continued during many years, the high nitrogen plots are the most susceptible to several diseases including rusts and *Epichloe typhina*. The potash-starved plots are, however, reported to be the first to succumb to wheat and mangold rust in bad years of disease. The normally-manured plots suffer much less from these diseases.[2]

At Woburn also the nitrogen plots in the manurial series (which has been running for over 30 years) are the most rusted.[3]

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[1] See page 65 of this Number.

[2] Russell, E. J. "Fertilisers and Manures," 1915: "Soil conditions and plant growth," 1912: "Soils and Manures," 1915.

[3] Spinks, G. T. "Factors affecting susceptibility to disease in plants." *Journ. Agric. Science*, V.

In France it has been found that a heavy dressing of nitrate of soda can, by itself, bring on an attack of grey rot in grapes, the parasite (*Botrytis cinerea*) being always present to some extent in most vineyards.[1]

Copious applications of farmyard manure are well known to predispose potatoes to blight,[2] and gooseberry mildew has been observed in England to be worst on the sappy growth induced by similar treatment.[3]

In tea manurial trials in India, my colleague Mr. Hutchinson informs me, the amount of the die-back disease of the twigs (probably caused by a *Glœosporium*) varied directly with the dose of nitrate of soda.

Examples from agricultural practice of this effect of nitrogenous manuring could be multiplied, and the phenomenon has been confined under the more rigorous conditions of water culture. It has been found, for instance, that both rust and mildew of cereals attack most severely the plants grown in nutrient solutions containing double or quadruple the quantity of nitrogen required for normal growth.[4]

Phosphates and potash both are reputed to have an influence in increasing disease resistance. The action is best established for potash, both by practical experience and scientific experiments. The evidence of the potash-starved plots at Rothamsted has already been referred to. So also in water cultures the plants grown in solutions in which the normal amount of potash was doubled or quadrupled, showed a reduction in the amount of rust and mildew in cereals, but the effect was not enough to counteract the injurious influence of an excess of nitrogen.[5] It is a common practice of growers of plants under glass, such as tomatoes in England, to check the ravages of various parasites by potash manuring. Kainit has also obtained a reputation in several cases as a preventive of disease and is believed to act through its potash content.

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[1] Delacroix, G. "Observations et recherches au sujet de la 'pourriture grise,' &c." *Bul. Mensuel de Renseign. Agricoles.*, April, 1905. "Maladies non-parasitaires des plantes cultivées," 1908, p. 355.

[2] McAlpine, D. "Potato diseases in Australia," 1911, p. 27.

[3] Salmon, E. S. "American gooseberry mildew," *Journ. Board Agric.*, XX, 1913 1914. Brooks, F. T., Petherbridge, F. R., & Spinks, G. T. "Experiments on American gooseberry mildew in Cambridgeshire," *ib.*, XXII, 1915-16.

[4] Spinks. *l. c.*

[5] *ib.*

Phosphatic manuring has been used with success in the control of root rot of tobacco and ginseng, caused by *Thielaria basicola.* But the fungus is a soil dweller and it is possible that the manure acts directly on it and does not affect the resistance of the host plants.[1] Phosphates also increase the resistance of potatoes to blight and in a good many other cases they seem to be beneficial. Two instances of the opposite effect have, however, been examined. In the disease caused by *Sclerotinia Libertiana*, a fungus which attacks a number of garden plants, superphosphate has been found to reduce resistance under certain conditions.[2] This fungus requires an acid medium for its parasitic growth and appears to have the power of secreting acid. In lime soils the acid tends to be neutralized and plants grown in such soils resist the disease. Heavy manuring with superphosphate restores the acidity of the tissues and enables the fungus to thrive. In the lettuce mildew, *Bremia Lactuca*, phosphates have also been found to reduce the resistance of plants grown in water culture.[3]

Thus each of the three most important plant foods, nitrogen, potassium, and phosphorus, is capable of influencing the resistance of plants to disease, and this influence is undoubtedly physiological in its nature. How they act is not known. The few indications we have of the effect of various fertilizers on the cell contents show that there is here a most promising field for investigation.

For instance, it has been established that heavy doses of nitrogen have an effect, in some cases, not only in causing the production of thin-walled cells, rich in sap, but that the composition of the latter is altered by increasing the quantity of reducing sugars and diminishing the quantity of organic acid.[1] In this connection it is interesting to note that lemon-growers in Italy find that nitrogenous manures give a less acid fruit, and as this is undesirable, and also the bushes become more liable to gummosis and the fruit to rotting, they counteract the effect by applying phosphates.[2]

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[1] Whetzel, H. H., and others. "Ginseng diseases and their control." *U. S. Dept. of Agric., Farmers' Bul.* 736; 1916.

[2] Laurent, E. "Recherches expérimentales sur les maladies des plantes." *Ann. Inst. Pasteur*, XIII, 1899: "Recherches de biologie expérimentale appliquée à l'agriculture," I, 1901—3.

[3] Marchal, E. "Recherches de biologie expérimentale appliquée à l'agriculture," I, 1901—3.

In the same way, the action of phosphates, particularly of superphosphate, on the cell contents is believed to result in an increase in the acid reaction of the juice, and this may be the explanation of the observed effects of phosphatic manuring referred to above.[3]

It has already been pointed out that organic acids are believed to play a considerable part in the immunity of plants to disease. But it must be admitted that the analytical basis for this belief is as yet scanty. It is obviously necessary to examine more closely the effect of various fertilizers on the cell contents. If it could be shown that substances such as the rapidly assimilable nitrates, that are known to predispose to disease when applied in excess, act always in the same manner on some single part of the cell contents, such as the acids, then a considerable step in advance would have been taken. Enzymic activity, on which fungi chiefly depend for reaching and making available their food, is often closely dependent on small differences in reaction. No one who examines the evidence can doubt that the fuller investigation of the influence of external conditions, soils, manures, climate, and the like, on the cell contents and particularly on the organic acids, is destined to shed much light on the obscure problem of physiological immunity. We have still a long way to go before we can equal for plants the knowledge gained by the physiologists and pathologists of the causes of human and animal immunity. But there is no reason to suppose that the difficulties are greater than those that have been so brilliantly surmounted by the latter investigators. I have indicated the direction in which I believe that progress lies, and one of my main objects in reading this paper is to appeal to agricultural chemists to give some attention to a field for investigation which has not been sufficiently explored, in order that they may help in the solution of one of the most important problems in agriculture.

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[1] Comes. *l.c.* p. 442.

[2] *ib.* p. 450.

[3] Delacroix, G. "Maladies non-parasitaires des plantes cultivées," 1908, p. 369.

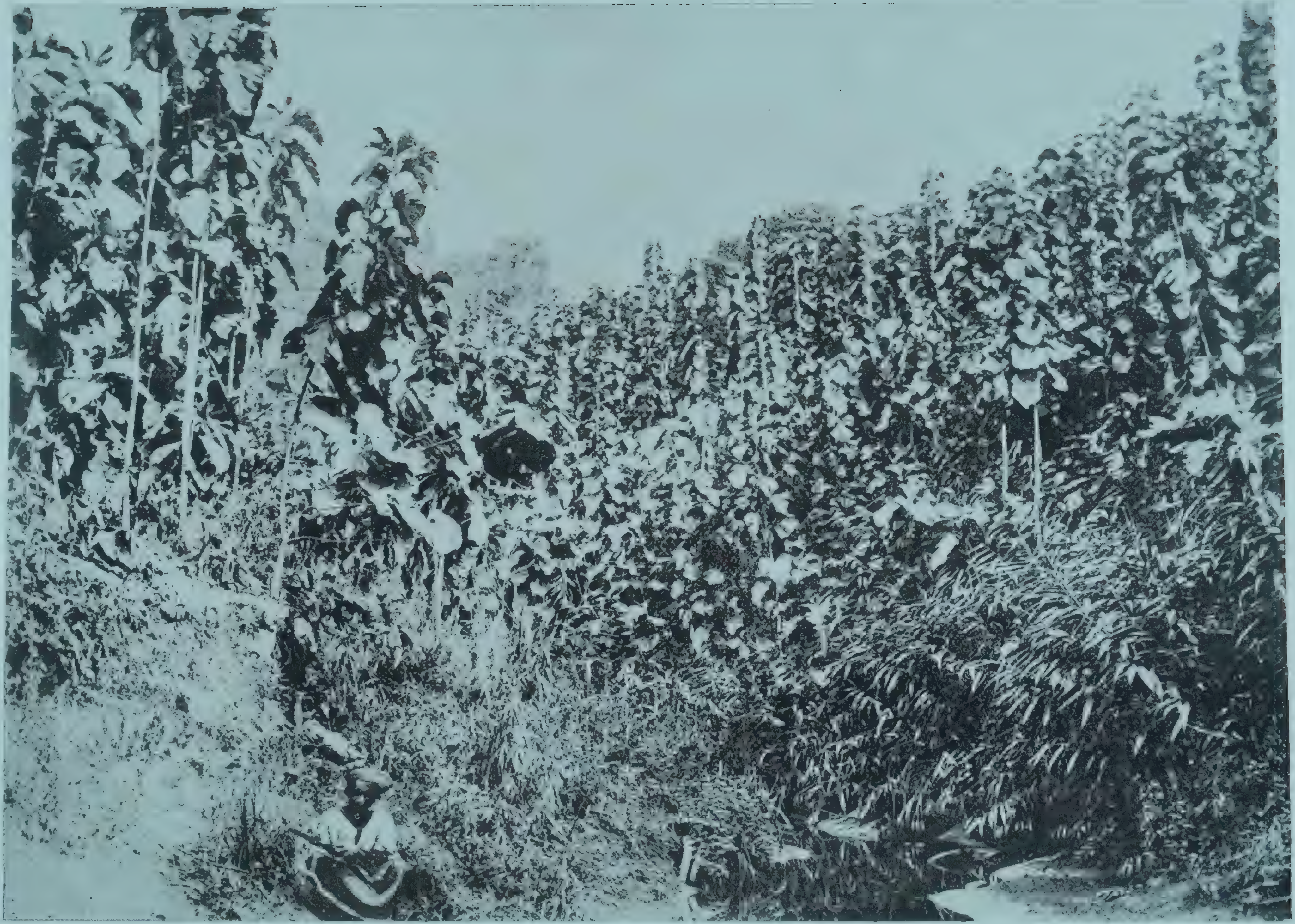

Photo by J. W. Oliver.

Teak plantation in Burma, three years old, formed by sowing teak seed in combination with the cultivation of a catch-crop.

THE ECONOMIC ASPECT OF INDIAN SILVICULTURE.

BY

EDWARD MARSDEN,

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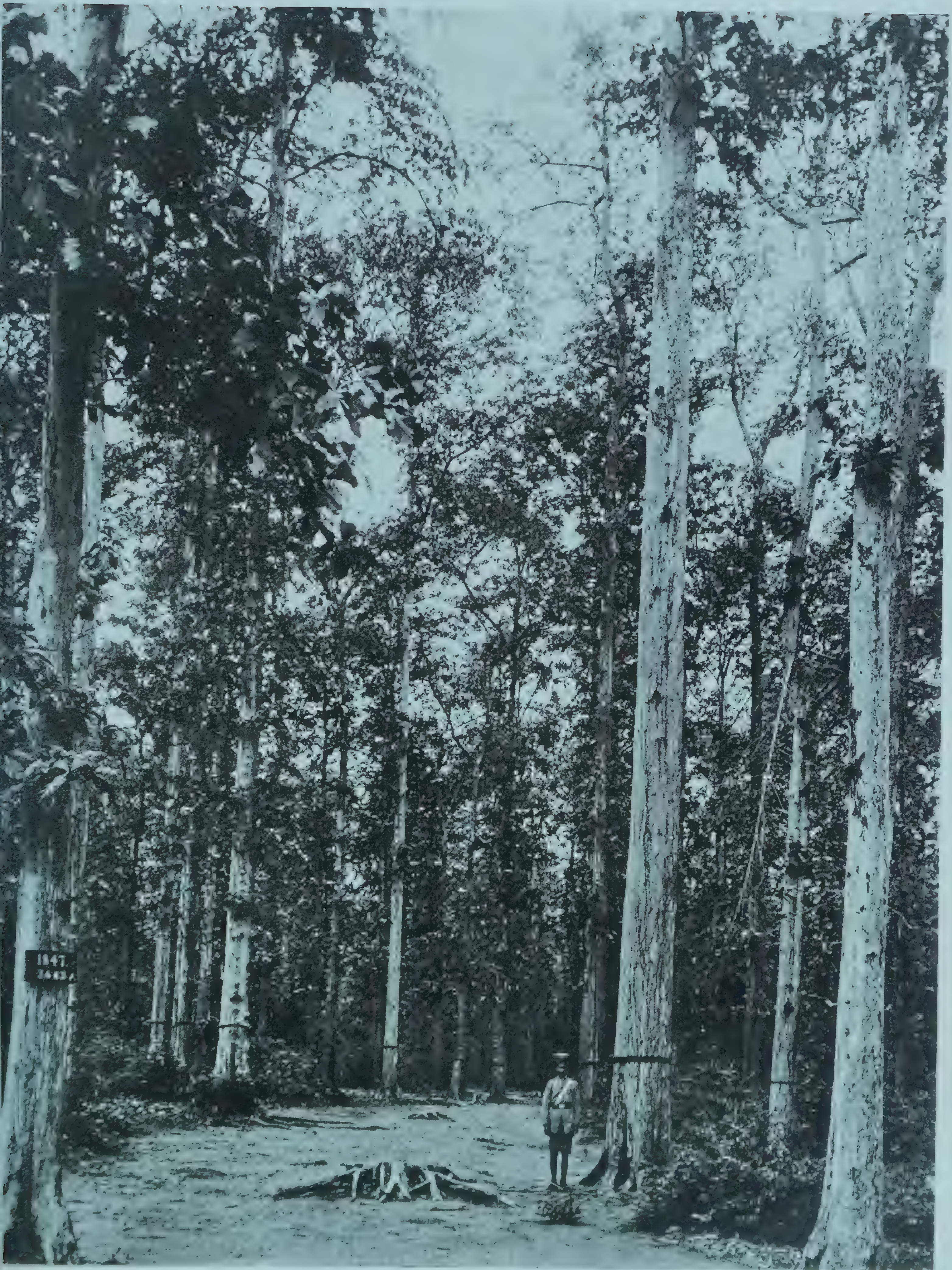
A CRITICISM often brought against the Forest Department in India is that it has not introduced modern methods of felling and extracting timber from the forests. The critic generally implies that we ought to follow the American plan of laying railways with portable extensions and of establishing a sawmill in the forest to cut up everything within reach. The construction of mechanical works of export depends on the trees growing close together and not scattered, and on the majority of the trees being saleable. It requires no great effort to understand that if 50,000 trees, instead of being dispersed over 50,000 acres, can be concentrated within 1,000 acres, the cost of export works for their exploitation will be greatly reduced, and the profits of the enterprise will be vastly enhanced. But in India the great majority of valuable trees grow scattered singly over large tracts, as in the tropical forests of Burma, Assam, and Madras; and even in the sal forests of Northern India, or in the deodar and pine forests of the Himalayas where the trees are all the same species, the stems of marketable size are generally distributed widely amongst smaller trees of all ages. Nevertheless concentrated exploitation is the way to make the greatest profit out of any forest, and the only way to make any profit out of the less accessible forests. Ideal conditions are exhibited in a forest consisting entirely of closely grown trees of valuable species, arranged in a succession of more or less even-aged crops. This aim has been fulfilled in the teak plantations at Nilambur in Madras, where this year the fellings over 21 acres have realized Rs. 1,54,500 net, or an average of Rs. 7,370 per acre. The best acre fetched Rs. 13,450 net, including cost of extraction; this plantation was 72 years old.

The silvicultural problem confronting every Indian forest officer is how to replace the existing forest containing trees of all sizes and often of great variety by even-aged blocks fully stocked with valuable species. There is only one way to do this: by taking in hand a tract of forest and methodically concentrating upon the clearance of all old trees within the selected tract, substituting for them within as short a time as possible a crop of vigorous young seedlings. The problem always resolves itself into a question of regeneration: how most cheaply and effectively to raise the young crop. Undoubtedly the cheapest is natural regeneration; in a virgin forest when an old tree dies and falls, or when a single mature stem is felled, its place is invariably taken by others which spring from seed cast by the surrounding trees. But the process takes time; though absolutely certain, Nature's methods are very slow. Moreover, the selection of single trees scattered throughout the tract precludes the possibility of concentrated exploitation. The trouble is that the larger the number of trees felled and the shorter the time-limit set to the period of regeneration, the greater is the risk of failing to restock the tract fully with vigorous seedlings. Yet, unless the time-limit is fairly short, an even-aged crop will not be produced, and the resulting stock may consist of trees as irregular in size as those of the forest which it is replacing. Natural regeneration is thus always a compromise between the demand of man for an even-aged, regular forest of considerable extent, and the natural character of trees to reproduce themselves over comparatively small areas and to form an irregular forest.

When dealing with trees whose silvicultural character had not been studied, in order to ensure the replacement of those felled, our predecessors had to proceed over small areas and to select either single stems or small groups for felling. But when some knowledge had been acquired of the demands made by the young seedling

PLATE II.



oto by R. S. Troup

Teak plantation at Nilambur, Madras, age 65 years, nearly mature.

upon moisture, shelter, light, and soil, the length of the regeneration period could be reduced, and the area of the tract taken in hand increased. With full knowledge of such demands, a time-limit of 10 to 20 years can reasonably be set for the complete natural regeneration of a tract of forest in a temperate climate. But even so, the young crop will vary in age from 1 to 20 years, and this degree of irregularity must be admitted in the compromise between man's demands and Nature's methods.

It is clear, I hope, that the cheapest way of replacing the existing irregular woodlands by even-aged blocks of forest, namely, natural regeneration, depends for its success primarily upon a knowledge of the young seedling's requirements. This is the point upon which silvicultural research should concentrate.

Proceeding from the dry, temperate climate of the Western Himalayas to the damp, temperate climate of the Eastern Himalayas and to the damp, hot climate of Assam and Burma, the variety of species increases greatly, and the difficulties of natural regeneration accumulate. Any break in the heavy cover of the forest caused by the death or the fall of a tree is filled at once with weeds, climbers, or softwoods. These forests may contain 200 or 300 different kinds of trees to the square mile, and there is generally present a lower storey of bamboos 60 to 100 ft. high. Growth is rapid, and communications bad. It is certain that felling trees here will not mean the destruction of the forest; something will come up, and very soon too. But nearly always what comes up is not what man wants. Supposing we wanted to obtain natural regeneration of teak in Burma: there are about 25 big trees of different sorts to the acre, and of these perhaps three are teak; under such conditions how is it possible to modify the shelter so as to favour the natural reproduction of teak to the exclusion of all the other species? And we are faced with the same difficulty whatever particular tree we may select. The only practical method in such tropical damp countries is to fell every tree and to restock by sowing or planting the kind we want.

In this connection, I should like to invite attention to the method of introducing trees by sowing the tree-seeds in combination with the cultivation of catch-crops. When the crops are reaped, the little trees remain to grow up into forest. By this means the seedling trees receive at little or no cost the advantages of weeding, tending, and soil-loosening. Results have been so encouraging that this method of forming plantations deserves the utmost attention wherever local conditions render its introduction practically possible.

We know that the unrestricted extension of plantations formed of a single species is dangerous owing to the risk of inducing a plague of insects or fungi. The policy then should be to form either mixed plantations or pure plantations of limited area. No two species make the same demands on light, moisture, shelter, or soil; almost always one kind grows quicker than another, and an irregular wood with widely-spaced, branchy trees results. The two points in timber for which the market is ready to pay a big price are length and freedom from defects. Branchy trees connote knots in the timber. Hence it is better to form pure plantations of moderate size rather than mixed plantations of larger area. The aim should be to establish pure plantations of 50 to 300 acres in extent, arranged so that adjoining plantations differ from each other in species and age.

The obvious step is to raise valuable trees like teak and rosewood. But it seems to me that further consideration is wanted. These hardwoods take 80 or 100 years to mature; throughout this long period not only are they open to danger from fire, insects, and fungi, but the return on the money invested in their production is deferred, and the plantations not yet mature represent a very large working capital. A timber-crop which could be realized at an earlier age, say 25 years, would be worth consideration even if the value of the wood were a good deal less. Assuming a rate of 4 per cent. compound interest, the present value of 1,000 cubic feet of hardwood, worth Rs. 5 per cubic foot to be realized after 100 years and thereafter every 100 years, is Rs. 101. The present value of 1,000 cubic feet of softwood, worth annas 3 per cubic foot to be realized after 25 years and thereafter every 25 years, is Rs. 112.

The specially favourable condition for growth which these tropical forests enjoy is the hot, damp climate. To utilize fully

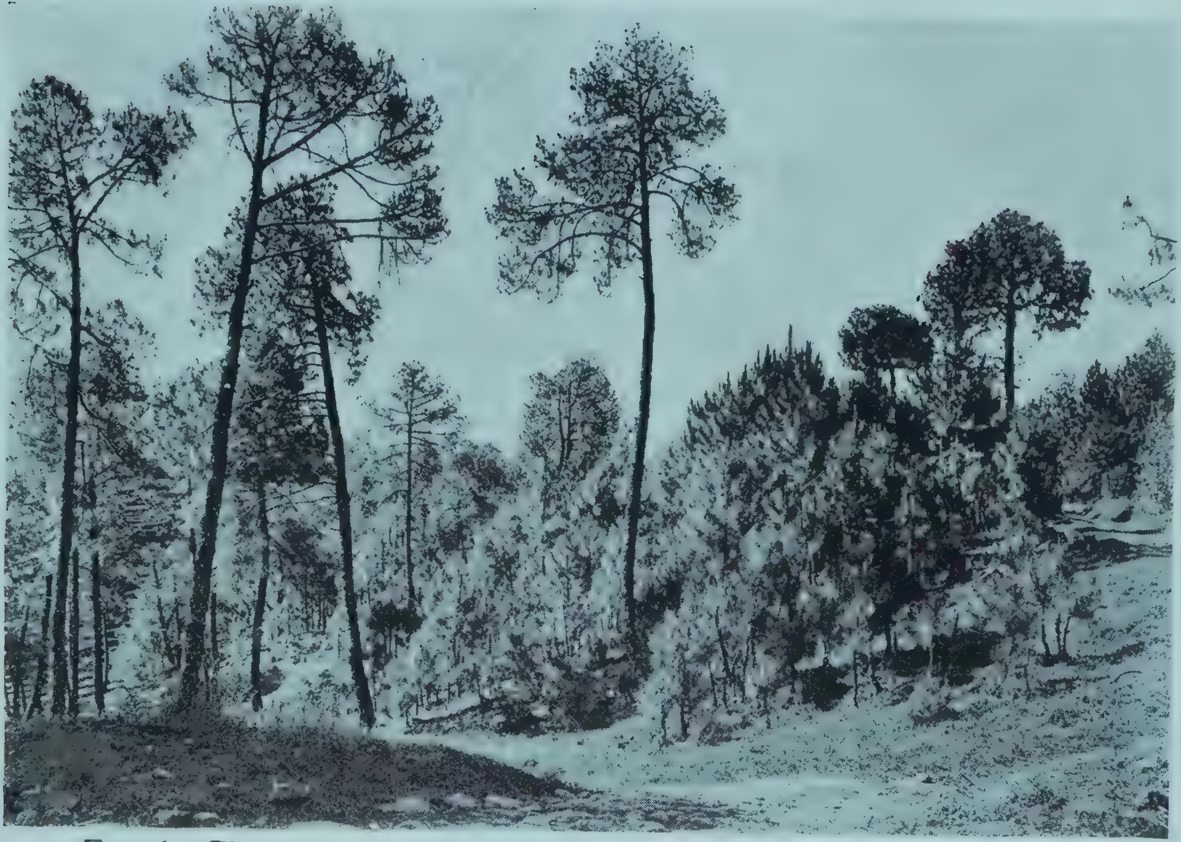


Fig. 1. Chir pine forest, closed to grazing, showing natural regeneration.

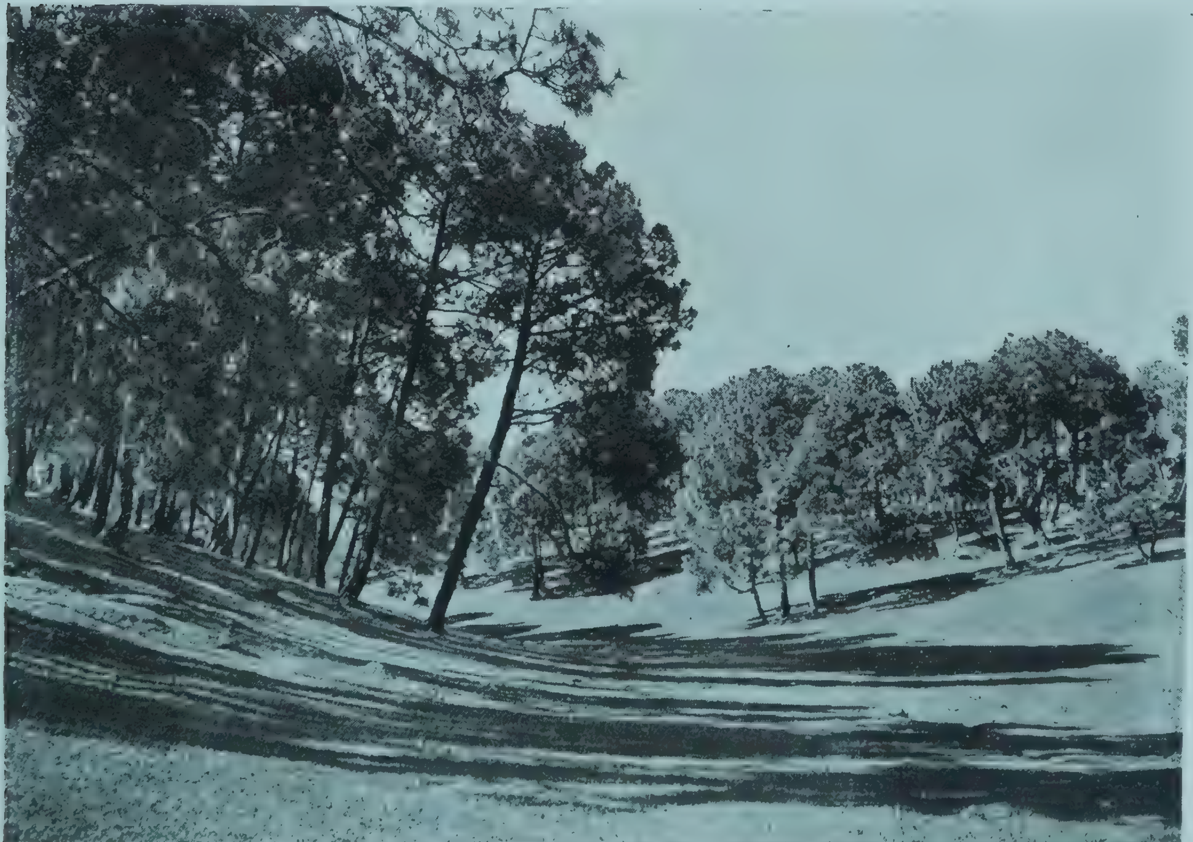


Photo by R. S. Troup.

Fig. 2. Chir pine forest, open to grazing, showing complete absence of natural seedlings

PLATE IV.

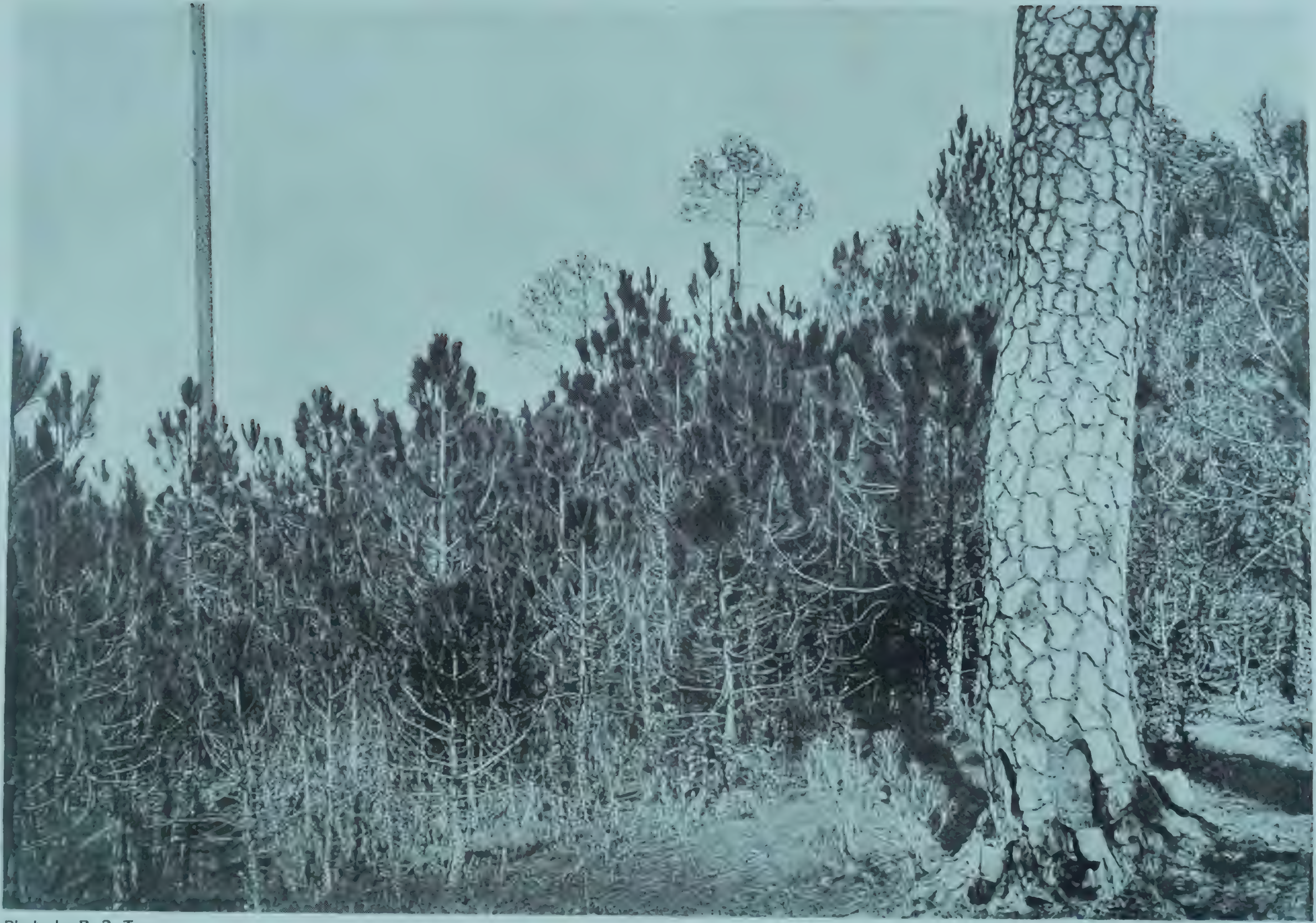


Photo by R. S. Troup.

Good natural regeneration of chir pine, showing seed-bearers being tapped for resin.

this favourable condition we should cultivate trees which can take advantage of it. The kind of tree which responds best to a hot, damp climate by extreme rapidity of growth produces wood either soft or only moderately hard, not generally considered valuable. Such trees are amongst others : *Bombax malabaricum, Anthocephalus Cadamba, Morus lævigata, Terminalia myriocarpa, Duabanga sonneratioides, Gmelina arborea, Albizzia moluccana, Albizzia stipulata.*

There is already a demand for wood to make tea-boxes, packing-cases, three-ply wood, matches, paper-pulp, and scantlings, which demand has to be met by importation from Japan and elsewhere, and which there is reason to believe will increase rapidly. For these purposes softwood such as is yielded by the trees mentioned above is as good as, if not better than, hardwood ; and there seems little doubt that, given the conditions of continuity in supply and good communications, a satisfactory price could be obtained for softwoods grown concentrated in pure plantations of fair size.

Here then is another point for silvicultural research : the best way to sow or to plant tropical trees, particularly fast-growing kinds.

Figures obtained from experimental plots in the forests indicate that by judicious tending, by a system of cleanings and thinnings started as soon as the young crop is established, it is possible to produce trees as tall and as thick as the market wants at a much earlier age than if the trees were left to grow up untended. Not only is the age of maturity lowered, but a handsome revenue is realized from thinnings. The number of trees which should be removed when thinning a crop varies with the kind of tree and with the fertility of the locality ; it is a fascinating study, and its economic significance is obvious.

There is a growing conviction in India that the forest resources of the country are not being adequately utilized, and the popular dissatisfaction is voiced in the demand of the Press for more thorough exploitation. The general opinion is correct : the forests are not being utilized as they might be if we knew how to replace the trees felled. But it seems advisable to enter a plea for caution. No industry can be developed or conducted successfully unless the sources of supply of its raw material are beyond suspicion in the permanency and approximate regularity of their output. It is of little avail to establish a factory only to find that the supplies of wood or bamboos run short after a few years. Hence before initiating a system of concentrated exploitation, economic forest management insists upon the silvicultural aspect being fully understood. In the case of timber, will it be possible to guarantee the progressive formation of new timber-crops which will be mature by the time the existing supplies are exhausted ? Unless the answer is affirmative, the expansion of industries dependent on forest produce, such as the tea-box industry, the tanning industry, matchmaking, and paper-pulp, cannot be based on a sound foundation.

The case of pulp is peculiar ; I am here considering only the utilization of bamboos. Should a heavy demand for bamboos over a certain tract arise, there would be great danger of overworking the more accessible areas : on the other hand, if the bamboos are too lightly worked, the area operated over would be needlessly large, and the cost of working unnecessarily high. The correct method of working bamboos so as not to reduce the annual production of new shoots is not yet thoroughly understood. Experimental areas have been under observation for 8 years, but the most economic treatment for varying localities is still a matter requiring much investigation. Another point about bamboos is the character of some kinds, including the two commonest in Burma, to flower and seed simultaneously over large areas, and then forthwith to die. These general flowerings occur at intervals of many years, but the length of interval and the causes, climatic or otherwise, which induce flowering have not been determined, so that it is not possible to foretell when the flowering will take place. It is clear that a general flowering would have most awkward results for a pulp factory depending on one of these species of bamboo for its supply of raw material.

These examples will suffice to show how necessary it is for research in silviculture to proceed *pari passu* with advances in methods of timber-export and in the development of new markets for

Photo by E. Marsden.

Plantation of *Bucklandia populnea*, 38 years old

forest-produce. The sympathy of the public is easily obtained for the utilization of what is already available in the forest and only waiting to be taken out. But those responsible for the encouragement of industry in India will realize that it is by silviculture alone that continuity and regularity of yield, a steadily improving quality of raw material, and concentrated exploitation can be guaranteed.

Silviculture must form the basis for economic development of our forest resources.

SOME METHODS SUITABLE FOR THE STUDY OF ROOT DEVELOPMENT.

BY

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AND

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In a paper[1] read before the Botanical Section of the Indian Science Congress at Bangalore in 1917, an account was given of the results obtained in the study of the root systems of the varieties of agricultural crops. It was suggested that this aspect of variety trials has been neglected in the past and that a study of the root system of a set of types throws a considerable amount of light on the results of field experiments. During the past year, the work has been continued and some of the results obtained are discussed in the present paper.

One of the difficulties in these investigations is to remove the soil so as to lay bare the distribution of the entire root system, including the finer branches. In the case of leguminous crops, it is also necessary to expose the nodules without damage. The best method so far found for use in fine, silt-like alluvial soils, like those at Pusa, is to remove the soil by means of a knapsack sprayer. By this means, two plants can be dealt with in an ordinary working day and all the fine ramifications down to the piliferous layer and the root cap can be traced without damage. With leguminous plants, great care is necessary if all the nodules are to be obtained attached to the roots.

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[1] Howard A., and Howard, G. L. C. *The Agricultural Journal of India*, Special Indian Science Congress Number, p. 17, 1917.

AN IMPROVED FORM OF POT CULTURE.

In soil-aeration experiments where it is necessary to study root development in relation to the physical condition of the soil, some method of growing a large number of separate cultures has to be devised. Ordinary field plots are out of the question, due to the permanent alteration in the physical texture of the soil that would be involved.

The ordinary pots used for culture work are also unsuitable for such investigations, for the following reasons :—

(*a*) There is inadequate space for root development, unless the pots are very large and deep.

(*b*) The normal circulation of the air and water, such as occur in the soil, is impossible in a culture pot even when unglazed and even when a sunk pot is used.

(*c*) Artificial drainage has to be provided in pots, which in itself acts as an aerating agent.

(*d*) Culture pots frequently introduce the temperature factor.

(*e*) Such cultures have to be constantly watered, an operation consumptive of much time.

(*f*) It is almost impossible to explore in detail the root system of a plant grown in a culture pot.

These difficulties can be overcome by using very small plots in the place of culture pots. Pits from three to six feet square are dug out to the depth of two to two and a half feet, the upper nine inches of soil being kept separate from the sub-soil. Various aerating agents are mixed with the soil, which is then replaced, care being taken to re-fill the pits a little at a time and to compress the earth to the required degree. If prepared a few weeks in advance and irrigated immediately, the contents of the plots resemble very nearly the conditions obtaining in field culture. The difficulties connected with the circulation of air and water are in this way removed and the temperature factor does not interfere with the results. In cases where the soil is mixed with large quantities of aerating agents, such as potsherds, broken bricks, sand or powdered charcoal, it is advisable to spread from half to an inch of ordinary soil on the surface of the beds to prevent any undue heating or cooling due to the higher conductivity of the aerating materials. Control plots of undisturbed soil and also of soil which has been dug out and then re-filled should be included in the series. Where both root development and yield of seed have to be determined, the plots should be in duplicate as the removal of specimens for root examination introduces a new aeration factor.

The differences in growth and root development obtained are very striking. Measurements of the length of growth or of the total weight can rapidly be obtained.

As an example of the kind of results obtained by this modified method of pot-culture, the following measurements in the case of Java indigo may be cited.

The effect on the growth of Java indigo of diluting the Pusa soil with potsherds and sand.

Kind of soil	No. of plants measured	Average length in cm.	Percentage increase
Soil only	33	36·7	0
Soil 1/2 + sand 1/2	36	51·6	40
Soil 9/10 + potsherds 1/10	33	48·3	31
Soil 7/10 + potsherds 3/10	35	50·9	38

In the early stages of the above experiment, water was a limiting factor in growth, due to shortage in the rainfall. Before the beds were watered, the figures obtained were the following :—

Kind of soil	Average length in cm.	Percentage increase
Soil only	32·4	0
Soil 1/2 + sand 1/2	36·3	12
Soil 9/10 + potsherds 1/10	37·6	17
Soil 7/10 + potsherds 3/10	37·9	17

These differences show how necessary it is in aeration experiments to exclude the soil moisture factor.

SOME INDIGO RESULTS.

The effect on the root system of complete or partial cutting back of rapidly-growing Java indigo has yielded some interesting results. In the cultivation of indigo in Bihar, it is the universal practice to cut the indigo back completely in June and to leave the stumps for a second crop. The time taken in forming new shoots varies with the season. In very wet weather, sprouting is delayed and the process is distinctly favoured by a break in the rains. It has frequently been observed at Pusa that if a few leaves are left at the first cut, the new growth is much healthier and much more rapid. This year, the effect of complete cutting back and of hard pruning on the root system was examined. It was found that complete cutting back while the plant is in active growth kills the fine roots and nodules and that a new absorbing system has to be produced before new shoots form. This naturally takes time. Heavy pruning, on the other hand, leads to far less damage to the roots and nodules, which at once explains the rapidity with which such plants form new growth. This fact may easily prove of considerable practical advantage to the indigo industry. If the crop could be grown in lines with interculture, it could be heavily pruned at the first cut and the second crop could be advanced by several weeks. A new system of growing Java indigo, based on these results, has been worked out at Pusa, which will be tried on the large scale during the coming monsoon.

TIMBER SUPPLIES IN INDIA.

BY

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The ever-increasing demand for timber in British India, which is an indication of prosperity, development, and a higher standard of living, is becoming year by year a more difficult problem to solve. India is no exception to the general rule, for both in Europe and America the same problem has to be faced, and in those parts of the world, where the lower classes are more educated, it is easier to evolve ways and means of meeting the difficulty, as though in some localities the people are very conservative, they are not to the same degree unwilling to give up their old methods, as is the case with the bulk of the people of India.

It is interesting to compare the consumption of timber per head of population in European countries with that in India; for instance, in England it is estimated that the annual consumption of timber per head of population is roughly 14 cubic feet, of which not less than 80 per cent. is imported timber; whereas in India the total out-turn of timber, not including firewood, is 104,000,000 cubic feet for a population of 315,000,000, or 0·3 cubic foot per head per annum of population. Now, it might reasonably be supposed that as the demand for timber per head of population in British India is far below that of England, the prices of timber would be lower in India, but the reverse is the case, for three reasons:—One being that the facilities to import timber are far greater in England, while the lead is much shorter; another, that it is one thing to meet the demand for forty to fifty million people, and quite another to do so for over three hundred million; and lastly, that owing to the unequal distribution of the forests of British India, the lead, and especially that by rail, is often very great. To illustrate the above points, let us take two parallel examples, *i.e.*, that of *Pinus excelsa* or " Kail," and *Pinus sylvestris* or " Scotch Pine," two timbers which in quality and the uses to which they are put are very similar. " Kail " timber was selling on rail before the war at R. 1-5 to 1-6 per cubic foot or 1*s*. 9*d*. to 1*s*. 10*d*. in English money, while the " Scotch Pine " on rail in England was selling at 1*s*. 4*d*. per cubic foot. Again, take the two best-known standard timbers of India and England, namely, teak and oak, the pre-war rates for the former were Rs. 4 or 5*s*. 4*d*. per cubic foot, and that of the latter 2*s*. to 2*s*. 4*d*. per cubic foot. The case is nearly the same with all other timbers, and it will be found that, generally speaking, Indian rates are much higher than European rates, which can be due to but one fact, and that is that in most localities in India the supply of timber is barely sufficient to meet the demand, while the cost of importing timber into British India is generally higher than that into European countries.

Before ways and means can be devised to remedy this position of affairs, it is necessary to consider to what uses timber is put in India. In the first place, the requirements of the agricultural population are very large and fairly distributed over the whole country : their chief requirements are for house-posts, rafters, timber for agricultural implements, carts, fencing-posts, and temporary bridging material. Again, there is a very large demand for constructional timber by the P. W. D., contractors, and private persons, while the Railways require enormous quantities of timber in the shape of sleepers, and it is probably in this connection that the supply is in greater deficit than any other. Industries, such as furniture-making, carriage-making, boat and ship building, cooperage, carving and engraving, turnery, the manufacture of packing cases, shingles, pencils, sporting requisites, etc., also require considerable quantities of timber, and unless these are available in large quantities, healthy development in such industries cannot be expected. Enough has been said to demonstrate the absolute necessity of maintaining and increasing the annual supply of timber in India, suitable to the many uses to which it is put, and as it must be accepted that the supply is barely sufficient to meet the demand, it is necessary to consider how it can best be increased without overtaxing the forests.

The first idea which will naturally arise in any one's mind who has given the question serious consideration, is the possibility of increasing the area under forests by the formation of plantations. This, in the long run, will be one of the surest ways of increasing the yield of our forests, but it must be remembered that timber takes a long time to grow, and that after establishing a plantation it requires just as much attention to bring it to maturity as any other crop ; we may therefore accept the fact that the first step to be taken is to increase the area under plantation, and to tend to the best of our ability the many plantations which have already been created by the Forest Department. Of equal importance to the creation of plantations is the more intensive management of the existing forests : this factor has been given much attention of recent years by the Forest Department, and a start has already been made ; but it is not difficult to realize that there are limitations to such work, and also to the creation of plantations, when we consider the limited staff available. There is a further argument very strongly in favour of not only creating plantations, but also for more intensive management in working the existing forests, and that is that, when considering industries of all kinds, it is absolutely necessary to have a concentrated crop, in other words, a steady annual yield of one or more species of timber from a limited area, suitable for the manufacture of special articles, such as, for instance, jute bobbins, carving, pencils, matches, rifle-stocks, sporting requisites, packing cases, etc.

The second suggestion to be made, by which the supply of timber may be considerably increased, is to use such timbers as are at present little known to the market, and which are sound good timbers if properly handled, but which in the past have been overshadowed by the better-known classes of timber at present on the market. In this connection it might be well to cite an example of what is actually happening, due to the ever-increasing demand and high prices ruling for the better-known classes of timber. In a

Division on the West Coast, for many years the only timbers which could be sold were teak, blackwood, and a small quantity of *Terminalia tomentosa ;* as the prices for these timbers rose, the contractors looked about for other species, such as *Lagerstrœmia microcarpa, Terminalia paniculata, Xylia dolabriformis, Vitex altissima, Mangifera indica,* etc., as substitutes and to help out the supply of the more valuable woods, and by degrees they have been able to create markets for these timbers ; and so the process has gone on until they are now able to sell some 10 or 15 species of timber, which twenty years ago had no value at all, except possibly for firewood. The same process is going on in Burma, where teak, In (*Dipterocarpus tuberculatus*), and Pyingado (*Xylia dolabriformis*) were, up to a few years ago, the standard timbers, but which, though still holding the first place in the market, are now being associated with Burmese hardwoods, which are coming to the front, and will no doubt be greatly developed in the future.

The introduction on to the market of timbers other than standard timbers is strongly advocated, though to develop a market for these timbers, special care must be taken in handling them during conversion. It is a well-known fact that many tropical timbers are hard, strong, and fairly durable, but that they have the defect of being very liable to split and warp when converted into planks, rafters, and scantlings, and it is therefore necessary to take special precautions to overcome these defects. Further, in order to develop markets for new timbers to the best advantage, they should be placed before the public in a good condition, and this is a point that has perhaps not received sufficient attention in the past. The moral is obvious, namely, that the timber should be seasoned in the way best suited to its individual characteristics, and that during the process of seasoning it should be very carefully stacked, so as to obviate warping and cracking. In both Europe and America the greatest attention is always paid to careful seasoning and stacking of timber, and the best methods of doing so for such species as commonly come on to the market have been evolved by long experience. In India we are not in that fortunate position, and relatively little attention has been paid to this subject. As we have some 2,500 species of timber in India, it has, as yet, not been possible to start experiments except with a very few of the better-known species, other than the standard timbers ; but so as to make a start, some 30 species were selected and over a thousand logs were laid down for seasoning in seven different ways, three years ago, and the results of these experiments should be available by the middle of 1918. To give a few instances of the results obtained up to date, it has been found by converting *Bombax malabaricum* timber from green logs, and by immersing the planks in water for two or three weeks, that good sound boards, showing little discoloration, are obtained ; whereas by allowing the timber to season in the log, and then converting it into planks, the timber is riddled by borers and the planks completely perish after two or three years. In the case of hardwoods, which are liable to crack, such as *Terminalia paniculata*, *Bassia longifolia*, and *Xylia dolabriformis*, the best results have been obtained by converting green logs, and stacking the converted material in a shady, level spot, with air space between the pieces ; on the other hand, it was found that by allowing timber to season in the log it splits very badly. Take another example, that of *Dalbergia latifolia*, "Blackwood," the experiments with which show that better results are obtained by seasoning the timber in the log than by converting green logs, as the timber in any case is not liable to split, while the colour is seriously affected by green conversion. When the final results of these experiments are available, a start will have been made to ascertain the best methods of dealing with a few of our better-known auxiliary species, and it will then be possible to extend these experiments in the light of experience gained to other important timber-yielding species.

There is a third method by which the indigenous supply of timber can be considerably fostered, and that is by preserving the timber with suitable antiseptics. This is quite an obvious proposition, as if by treating timber you can double or treble its life you decrease the demand in the same proportion. India is probably the only country where this procedure of eking out supplies has not been adopted ; thus, in both Europe and America, you would find difficulty in naming any railway which does not run almost entirely over treated sleepers, nor is it the practice in those continents to place in water timber which has not first been antiseptically treated, and the same applies to a more limited extent in building construction. The reason why India has not adopted these Western methods is that we have a certain number of timbers the durability of which, even in tropical climates, is extraordinary, and also that up to within recent years the supply of timber has been more nearly equal to the demand. The time has, however, come when we shall have to adopt the idea of treating timber, both in order to more equally balance the supply and demand and also to enable us to introduce on to the market the less durable species which are mechanically strong enough and otherwise suitable for a variety of purposes. It is not proposed to go into details as to the treatment of timber, though from extensive experiments carried out up to date it has been demonstrated that the treatment of certain Indian timbers, with a good creosote oil, has doubled and trebled their life, both when used as posts and in the shape of sleepers, and as a good grade of coal-tar creosote can now be obtained in India at a suitable price, there appears to be no reason why the treatment of timber should not be generally adopted. The question how best to introduce the antiseptic depends on —

(i) the quality of timber;
(ii) the purpose to which it is to be put;
(iii) the size of the material; and
(iv) the quantity to be treated.

If large-sized timber of hardwood species is to be treated in large quantities, it will generally be advantageous to treat it in a pressure plant; on the other hand, when such material as fencing-posts, posts and rafters for construction, bridging material, or again a limited number of sleepers are to be treated, a portable open tank, fitted with the necessary heating apparatus, is advocated. I would strongly urge for the consideration of those persons who have to deal with such timbers in relatively small quantities to consider the possibility of treating their timber; as by doing so it will enable them not only to prolong the life of the timber, but also to utilize inferior timbers, other than the standard species, namely, teak, deodar, or sal, thus reducing their capital expenditure without sensibly impairing the quality of their work.

There is a fourth way by which the supply of timber may be increased, and that is by the development of communications in our forests, such as by the construction of roads, tramways, waterways, timber slides, etc.; but this is entirely an engineering problem, though, be it remembered, one of vital importance.

And lastly, there is the question of imported timber: at present our imports and exports, in normal times, are approximately equal, though the balance is slightly in favour of the imports. How far it will be found necessary to increase the importation of timber will depend on the steps taken to increase and intensify the management of our forests; to the introduction of species other than those at present known on the market, and this by proper seasoning and stacking of timber before sale; by the introduction of correct methods of antiseptically treating timber; and by the improvement and extension of the lines of communications in our forests.

OXIDASES: WITH SPECIAL REFERENCE TO THEIR PRESENCE AND FUNCTION IN THE SUGARCANE.

BY

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I. Introductory and Historical.

WHILE engaged in studying the different stages which lead to the formation of sucrose in *Saccharum officinarum*, it was found of utmost importance to know something about the influence which the enzymes present in the plant exercise over the synthesis of sucrose in particular and other carbohydrates in general. The important rôle which the organized ferments play in the economy of the plant is every day receiving increasing attention, which its importance rightly deserves. The problems involved in the study of the Chemistry of the Living are far more complex than what we meet in Inorganic Chemistry, and the study of the nature and function of the ferments present therein is, if not the most important, at least one of the most important means of tackling these. The sugarcane is found to be rich in the possession of a host of these enzymes, *viz.*, Oxidase, Catalase, Reductase, Protease, Invertase, Lactase, Emulsin, and a number of others. It was proposed to study these in some detail and correlate their activities with the presence of sucrose and other carbohydrates in the sugarcane at different periods of its growth. The ferment to be first studied was oxidase. On reference to the large amount of work that has been done upon the subject, it was found that while the majority of workers regard these substances as truly enzymic, there are some, a very small minority, who doubt this. So it was decided to undertake a rather exhaustive investigation, with a view to elucidate this and a number of other points.

Ever since Yoshida's[1] discovery of laccase in the lac tree and Bertrand's researches extending over a number of years, the study of oxidases has been receiving wide attention. Their presence has been demonstrated in a large number of vegetable tissues, organic secretions, muscles, and other animal products. Bertrand's idea was that they are universally present in plants. Moore and Whitley[2] first questioned this view and showed them to be absent from the fresh fruits of lime, lemon, and orange. However, Ewart[3] showed that the failure of these authors to get a positive test for oxidases is due to the presence of acids. Later on, Atkins[4] and Keeble and Armstrong[5] demonstrated the presence of other inhibitors whose influence must be removed before any positive oxidase reactions can be obtained. In 1911, Hunger studied the oxidase and peroxidase reactions of the coconut milk, while at the same time Gruss ascribed the production of transitory starch as depending upon the action of temperature and oxidases. Between the years 1902 and 1904 Bach and Chodat[6] published a series of papers embodying their views on the function of peroxidase in the living cell. They showed that the so-called oxidase is a mixture of two enzymes, oxygenase and peroxidase, the first being concerned in the production of peroxide from atmospheric oxygen and the second in acting upon this peroxide and making its oxygen available for the oxidation processes going on in the cell. This theory was criticized by Moore and Whitley[7] according to whom peroxides exist ready formed in the plant without the intervention of any enzyme and it is the function of the oxidase to act upon this and liberate the oxygen which can be employed in carrying out further oxidation processes necessary for the plant growth. In 1901 Kastle and Loevenhart[1] advanced the view that the oxidase is not a true soluble ferment but an organic peroxide. The part played by oxidases in the coloration of tea and coffee has been investigated by Aso[2] and Gorter[3] respectively ; the influence of oxidase on the ripening of fruits and roots by Brooks,[4] Thatcher[5] and Appleman,[6] the relation of respiration to oxidase by Bach[7] and Reid,[8] of pigment and colour production by Bailey,[9] Keeble and Armstrong[10] and others. Quite recently Bunzel and Reid have studied a number of important problems in connection with the subject.

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[1] *J. C. S.*, XLIII, p. 472, 1883.

[2] *Bio. Chem. Journ.*, IV, p. 136, 1909.

[3] *Proc. Roy. Soc.*, B, 1915, p. 284.

[4] *Sci. Proc. Roy. Dub. Soc.*, XIV (n. s.), Nos. 7, 8, 1.

[5] *Proc. Roy. Soc.*, B, 85, 1912, p. 214.

[6] *Bio. Chem. Zeitsch.*, 1913, 50, pp. 185—208.

[7] *loc. cit.*

II. Experimental.

1. *Detection of oxidase in the sugarcane and its action on various reagents.*

All the oxidases have this property in common that they blue tincture guaiacum, either with or without any hydrogen peroxide. Hence blueing of guaiacum tincture has come to be regarded as a test for the presence of oxidases. We find that the sections of the cane from the node or the internode portion, the juice from the leaves, the stem and the roots, all respond to this test. It was further found that the positive reactions are obtained with benzidine, hydroquinone, L. napthol, pyrogallol, salicylaldehyde, toluidine, paraphenylenediamine, phenol-phthalin, and indophenole reagents ; while the reaction is negative with carvacrol, eugenol, tyrosine, and vanillin. The positive reactions develop better and comparatively sooner in solutions where hydrogen peroxide is present than where this is absent. Thus tyrosinase is found to be absent from the cane, while the presence is shown of laccases and aldehydase.

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[1] *Amer. Chem. Journ.*, 1901, 26, pp. 539—566.

[2] *Bull. Coll. Agric. Tokyo. Imp. Uni.*, 1901, IV, No. 4, pp. 255—259.

[3] *Annalen*, 1908, 359, pp. 217—244.

[4] *Journ. Amer. Chem. Soc.*, 1912, XXXIV, p. 67.

[5] *Journ. Agric. Res* , V, No. 3

[6] *Bot. Gaz.*, LII, p. 306, 1911.

[7] *Arch. Sci. Phys. Nat.*, 1913, 35, pp. 240—262.

[8] *Journ. Bio. Chem* , 1915, 22, pp. 99—111.

[9] *Bot. Gaz.*, L, 1910.

[10] *Proc. Roy. Soc.*, 1912, B, 85, pp. 214—218, and *Journ. Genetics*, 1912, 2, pp. 277—311

2. *Preparation of the oxidase extract.*

The leaves, stems, or roots from whatsoever source it was desired to obtain the extract were first sliced finely in a hand-slicing machine and then crushed in an iron pestle and mortar, with the help of well-washed sterilized sand. Water is added during crushing if required. The pulp so obtained is taken up with water and kept soaked under it for about six hours, when it is pressed out through a thick cotton cloth. The extract so obtained is filtered either over Buchner or through Birkfield porcelain candle, when a strong oxidase extract is obtained, which can keep for a number of months if a little chloroform be added as a preservative or preventive of decay by bacteria.

3. *The phenomenon of browning and the chromogen of the cane.*

It has been observed that when sections of sugarcane are out and left exposed to the atmospheric oxygen, they gradually begin to brown. This browning of the freshly cut surface of a number of plants and fruits has been observed by a number of workers and is universally ascribed to the action of oxidases. The cane extract also just after filtration through Buchner begins to brown rapidly. The browning so noticed seems to be due to the oxidation of the chromogen of the cane by atmospheric oxygen through the agency of the oxidases. The chromogen concerned seems to be some substance allied to tannins, for it can be removed by shaking the extract with hide powder and filtering. The juice so clarified again begins to brown if some drops of a dilute solution of tannic or pyrogallic acid are added. Tannic acid present in the juice does not seem to belong to the gallotanic acid group, for when the extract is treated with lime-water we get a red precipitate characteristic of the oak tannins instead of the blue precipitate with gallotanic acid. The solutions of gallic, tannic, and pyrogallic acids were prepared and simultaneously with cane extract were treated with lime-water, ferric chloride, potassium cyanide, lead nitrate, gelatine, and sulphuric acid. The reactions obtained with cane juice while differing entirely from those with gallic acid and tannic acid resembled those with pyrogallic acid.

Miss Wheldale[1] has published an interesting paper on the subject of browning and chromogen in plants which give direct guaiacum reaction without the addition of hydrogen peroxide. According to her, the browning of tissues on mechanical injury or exposure to chloroform vapour and the power of blueing guaiacum directly are both associated with the presence in the plant of pyrocatechin. All attempts to extract pyrocatechin from cane extract with the help of alcohol and ether entirely failed in the hands of the author. The cane extract also failed to give any blue with guaiacum, which had been previously deprived of its peroxide by treatment with animal charcoal, even on the addition of alkaline pyrocatechin which had been allowed to brown on exposure to atmosphere; but the addition of a drop of a very weak solution of hydrogen peroxide (0·03 per cent.) brings the blue at once. Potato which blues ordinary guaiacum directly also behaves similarly as cane juice. These reactions with potato show that the substance responsible for giving blue coloration with charcoal-treated guaiacum is not pyrocatechin, as suggested by Miss Wheldale, but some peroxide as Moore and Whitley think; and contrary to the view of these latter authors it is not present in potato juice naturally as such but must be added from outside, either in the natural form with guaiacum not treated with charcoal or as free hydrogen peroxide when charcoal-treated guaiacum is used.

In order to further test Miss Wheldale's pyrocatechin theory we took a number of plants* of the orders mentioned by her and which ought to give direct guaiacum reaction. The extracts from

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[1] *Proc. Roy. Soc.*, B, 84, p. 121, 1911.

* *Plants*		*N. Orders*
1. Pudina (*Mentha Viridis* Linn.).	..	Labiatæ.
2. The rose.	..	Rosaceæ.
3. Aru (*Prunus persica* Benth., H.K.)	..	Do.
4. Lasura (*Cordia myxa* Linn.)	..	Boraginaceæ.
5. Sann-hemp (*Crotalaria juncea* Linn.)	..	Leguminosæ.
6. Indigo (*Indigofera tinctoria* Forsk.)	..	Do.
7. Radish (*Raphanus sativus* Linn.)	..	Cruciferæ.
8. *Bryophylium Calcinum* Salisb.	..	Crassulaceæ.

none of these plants, however, gave positive reaction with carbon-treated guaiacum on the addition of brown pyrocatechin solution, whereas with untreated guaiacum or on the addition of hydrogen peroxide when treated guaiacum was used, the blue colour was obtained at once, the intensity of the colour depending upon the more or less amount of hydrogen peroxide. From the above experiments and discussion it is apparent that direct guaiacum reaction depends more upon the presence of peroxide than upon that of pyrocatechin.

All the above plants were tested for the presence of pyrocatechin. The crushed mass was treated with alcohol, chloroform, and ether, and the extract so obtained evaporated to dryness on the water bath. It was taken up with water and tested with ferric chloride and sodium carbonate solution. Positive reactions were obtained with Pudina, Rose, and Aru; doubtful with Radish, Lasura, and *Bryophylium*, and negative with Hemp and Indigo.

4. *The action of preservatives.*

The cane extract on keeping deteriorates and soon moulds begin to be formed, specially when in contact with air. In order to prevent this decay some preservative must be added. For the purpose, the action of chloroform, toluene, and ether was studied. The leaves of the cane were crushed with these preservatives added from the very beginning and the extract obtained as usual. The action of these extracts was studied on a number of oxidants. The same colour reactions are obtained with all the three extracts, only they are somewhat more speedily obtained with chloroform than with ether.

The effect of these reagents was studied in another way. To 100 c.c. of the leaf extract obtained without any other previous treatment with any preservative, 5 c.c. each of chloroform, toluene, and ether were added. The time taken for the appearance of guaiacum blue and the blue due to the liberation of iodine from hydroiodic acid under the influence of oxidase was taken as a measure of oxidase activity. It varies directly with the quantity and quality of the active oxidase present. Again, the oxidase extract is acidic from the very beginning and the amount of acid present increases as the extract deteriorates ; so any increase in the amount of acid is a sure sign of decay. The results obtained are as under :—

1. *Acidity* (*in terms of NaOH N/50 required to neutralize* 5 *c.c. of juice.*) :—

	Toluene	Ether	Chloroform
After 24 hours.	2·2	1·8	0·8
,, 48 hours.	2·5	2·3	0·8

2. *Potassium iodide starch reaction* (5 c.c. juice ; 2 c.c. K1 aq. 10 per cent. ; 2 c.c. ½ per cent. starch paste ; 10 c.c. water ; and three drops 20 per cent. sulphuric acid) :—

Time taken for the blue colour to appear.

	Toluene	Ether	Chloroform
After 24 hours	Nil during 10 minutes	Nil during 10 minutes	35 seconds
,, 48 ,,	Do.	Do.	45 seconds

3. *Tincture guaiacum.* (Both carbon-treated and untreated.) (5 c.c. juice—0·2 c.c. guaiacum.)

	Toluene	Ether	Chloroform
After 24 hours	—	—	Instantaneous
,, 48 ,,	—	—	Do.

It is found that if we increase the quantity of the guaiacum used positive results are obtained even with toluene and ether extracts, the former taking 1·6 c.c. and the latter 0·8 c.c. of fresh guaiacum.

Thus it becomes quite clear that the chloroform exerts by far the best preserving influence.

Working on the oxidases of the tea leaf Mann[1] found that the oxidase is destroyed if kept in contact with chloroform vapour. Our experience, however, is quite the contrary. An extract freshly prepared was divided into two portions in stoppered flasks, one of these was kept with chloroform and the other without any preservative. It was found that the extract without any preservative begins to ferment and gradually the colour changes from deep brown to pale yellow with the formation of a whitish brown precipitate. After three months it was found that the pale yellow extract has lost considerably its original power of blueing guaiacum, and after seven months gave no blue even on the addition of hydrogen peroxide. The one with chloroform retained its activity even after 14 months, although the blue obtained was tinged with green. On the addition of hydrogen peroxide it changes to deep blue.

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[1] "Ferment of the tea leaf." Indian Tea Association, 1901.

5. *Effect of medium on the action of the oxidases.*

The plant extract as prepared in the usual manner after passing through Birkfield filter was slightly acidic. A portion of it was rendered alkaline to litmus by the addition of some drops of ammonia, and the other corresponding sample was kept in its original acidic condition. On applying the oxidase reactions it was found that better colour reactions are obtained in alkaline media than in acidic.

When the acid is added to the extract from outside, the guaiacum blue takes longer in coming, the time taken depending directly on the amount of acid present. Thus it was found that in one sample of extract prepared about one month previously, a concentration of 2·08 parts per 10,000 was sufficient to stop the reaction ; while in another freshly prepared sample 1·04 parts per 10,000 was quite sufficient to bring about this result.

The effect of the addition of dilute sodium hydroxide solutions was also tried. The action of alkali is to change the blue colour to green. The results may be thus summarized. The effect of increasing the amount of alkali, up to a certain limit, is to retard the appearance of blue. However, when the blue gives place partially to green, the time taken by the reaction gets less and less so that beyond a certain limit, the green comes instantaneously. On further addition of alkali, however, a concentration is reached when green also disappears giving place to a dirty yellow, the colour due to the action of the caustic soda on tincture guaiacum itself.

When the nature of the medium has such a strong influence, it is just possible that the difference in reactions observed in different samples compared may be due to the differences in the alkalinity or acidity of the cell sap, rather than to any difference in the quantity of the oxidase present. Pavy and Bywaters[1] have demonstrated the influence of environment in the case of aqueous extracts of yeasts. They found that the inverting power of yeast juice is greatly increased by the addition of acetic acid. The activity given by acid addition is susceptible of removal by a basic substance. The authors give a number of cases where the enzyme action in different samples is accelerated or inhibited by changing the reaction of the media in one direction or the other, and conclude that the activity is determined by the state of the environment. With the metabolic changes into which enzyme action enters sequences occur from the demand existing. Inactivity passes into activity as the demand arises for the changes, and circumstances reasonably point to the environment constituting the medium through which the issue is worked.

It has been found by a number of workers[2] that the "oxidases" work best in alkaline medium. Our study of the cane oxidase, however, does not bear out the conclusion. We have shown that the presence of acid to an extent to which it is present in the plant is not harmful to cane oxidase. Besset and Thomson[3] found that the oxidase in some fruits, such as apples, pears, and walnuts, is active only in slightly acid solution.

Even granting that the oxidase reactions are accelerated in alkaline medium, it cannot be presumed that the alkaline medium is one best suited for plant growth. In the laboratory of the plant there are taking place a number of other reactions, enzymic or otherwise, which may work best in acid medium. And we know as a matter of fact that some of these do require an acid medium. The plant has to look to the requirements of these also and cannot "help" the oxidases at the expense of the other reactions. Again it may not be in the interest of the plant growth that the oxidases may have a reaction velocity greater than what they have in originally acid medium. The slow rate at which the oxidases work in acid medium may be best suited to the assimilation of the products of oxidation, which otherwise being formed too rapidly will accumulate and may have a toxic effect or otherwise retard the growth of the plant.

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[1] "On the governing influence of environment on enzymic action:" *Journ. Phys*, 1910, XLI, p. 14.

[2] Rose. "Oxidation in healthy and diseased apple bark." *Bot. Gaz.*, 1915, LX, p. 55; Jules Wolff. "Existing action of alkali specially ammonia on peroxydase." *Comp. rend.*, 1912, 135, p. 484.

[3] *Journ. Amer. Chem. Soc.*, 1911, XXXIII, p. 416.

6. *Strength of oxidase in different portions of the cane.*

The term strength here should be taken to depend directly upon the amount of substrate oxidized, *i.e.*, to the intensity of the reaction and may be due to the quantity or activity of the oxidase or may be the joint effect of both these. Tincture guaiacum and pyrogallol were used for the purpose. The results obtained are summarized below :—

A. The cane stem was divided into two portions and their activity compared. It was found that the upper gives a stronger oxidase reaction than the lower.

B. *Rind and pith.*

1. The cane was stripped of its rind, and the rind and pith so obtained were crushed separately and their activity compared. It was found that the rind was far stronger than the pith.
2. Rind from different portions of the cane. Rind from the upper portion of the cane was stronger than from the lower, and that from the lower stronger than from upper.
3. Pith from different portions of the cane. Pith from middle portion of the cane was stronger than from upper, and that from the upper stronger than from lower.

C. *Nodes and internodes.*

Although the weight of the nodes as compared to that of the internodes in the cane is much less, still they contain about 25 per cent. more of the active oxidase than the internodes. Again, both the nodes and the internodes from the upper regions of the cane are stronger than from the middle and from the middle, stronger than from the lower.

D. *Leaf and stem.*

The oxidase in the open flat portion of the leaf is stronger than in the sheath leaf, *i.e.*, curled up portion of the leaf, and stronger in this latter than in the stem itself.

The above results seem to be quite in economy with the requirements of the plant. Those portions which are physiologically more active contain more of the active oxidase than the others; for instance, the leaf and the adjoining greenish portion of the cane are richer in oxidase than the stem, and we know that leaf is the seat of all photosynthetic processes. Again, nodes which are in direct connection with the leaves are stronger than the internodes. The rind is stronger than the pith. This may be explained from the point of view of the protection of the plant against mechanical injury or the attack of parasites such as *Trichosphæria sacchari* and other similar fungoid pests. When injured the oxidase comes in contact with the colourless precursor of pigment and oxidizes it into a substance which has toxic properties. Again, we know that the stem of the cane is the storage organ of the plant to store the sugar manufactured in the leaf, and the lower portion of it near the bottom is much richer in sucrose than the upper. Hence whenever the plant may have to fall upon its reserve food for energy supply it will have to take it from the sugar stored, which however to be of any use for plant growth must at first be oxidized. Thus it is quite in keeping that the lower portion of the cane may be stronger than the upper in oxidase activity, specially so with the ripe canes where the lowest portion of the stem contains more sucrose.

7. *Effect of boiling the oxidase extract.*

One of the chief properties of the enzymes is their sensitiveness towards heat. On heating their solutions to the boiling point, they cease to be active and the activity does not return on cooling or by any other subsequent treatment. It was found by us that the activity of the oxidase extract, though apparently destroyed on boiling, is in fact only suspended temporarily. It regenerates itself on cooling and keeping to an almost the same extent as before. It is immaterial whether the juice used has been clarified or not. The regeneration is more complete with clarified than with unclarified, however. This destruction of the oxidase bears an inverse proportion to its amount present in the solution. In contradiction to the observations of Bach and Chodat[1] the activity returns even on boiling the juice twice. We cannot confirm Doney-Henault's[2] observation that the oxidase is destroyed on boiling owing to the production of acid during the process. We could not detect this increase in the amount of acid on boiling.

Mechanism of the process of oxidase regeneration from their boiled solutions. We have observed that *immediately* after boiling the plant extract, its oxidase activity seems to be almost destroyed, but returns on keeping the boiled extract. Up to a certain hour the regeneration is proportional to the time of keeping, when it reaches the maximum value, and further keeping will bring in no more revival of the activity. The extract loses some of its activity permanently, however small may be this loss. This phenomenon can be explained by assuming the " oxidase " as a system rather than a single compact molecule ; the different components in the system being connected with each other by bonds or affinities which are liable to break on the application of heat. When an oxidase solution is boiled, most of these " oxidase molecules " get separated into different components. A certain percentage of these components undergo further constitutional changes at the high temperature and are thus permanently thrown out of the oxidase system. But having been thus destroyed they may act as a protecting shell or screen to the remaining disrupted components up to a certain extent. These disrupted molecules are thus saved from a permanent destruction and on keeping gradually combine again to regenerate the complete oxidase system. There may be still a portion—

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[1] *Ber. d. dent. Chem. Gesell.*, 1903, 36, pp. 600—605.
[2] *Bull. Acad. Voy. Belg.*, 1909, pp. 342—409.

although a very small percentage—of the total oxidase molecules, which has escaped any disruption altogether and is quite intact. This represents the portion of the oxidase molecules which give the positive blue reaction with guaiacum immediately after cooling. This residual power of blueing guaiacum, although quite small, is quite distinct in many samples.

In view of the facts stated above, we must hesitate to classify the oxidase as an enzyme. If it is enzymic in character, it is the only example where an enzyme has not been destroyed on boiling its solution even twice or when it has again regenerated itself on keeping, and our conception of an enzyme must undergo a radical change.

8. *Action of reducing agents on the oxidase.*

Moore and Whitley found that the oxidases are extremely susceptible to the action of reducing agents, so much that they are completely and irrecoverably destroyed. We can very well understand this sensitiveness if the oxidases are enzymic in character. However, we are able to confirm these authors only partly. A long and systematic study of the action of hydrogen sulphide upon oxidase under widely differing conditions was undertaken. The extract was tested boiled and unboiled ; clarified and unclarified ; clarified boiled and unclarified boiled ; and in the presence and absence of chloroform as any preservative. The regeneration of activity was studied with guaiacum tincture and starch potassium iodide reagent. The results of our experiments may be briefly summarized thus. The effect of sulphuretted hydrogen is merely to inhibit the activity temporarily and never to destroy it permanently. In course of time the oxidases are able to recover from the toxic effect of H_2S, much sooner when chloroform is present and exercising its preservative action. Even those samples which had been subjected to the double treatment of boiling and the action of hydrogen sulphide simultaneously, are able to recover their activity if kept sufficiently long. On clarification the oxidase extract does not immediately give positive reaction with starch and potassium iodide reagent. Even this clarified juice when boiled and treated with H_2S, recovers its activity if kept sufficiently long. It cannot be said with any amount of certainty whether it is the same oxidase which was originally present in the extract that recovers from the effect of these drastic treatments, or this original oxidase being destroyed by combining with H_2S or removed by clarification a fresh quantity is regenerated from some precursor of it which is present in the extract and is either not affected at all or very slightly affected by these different treatments. As we had an occasion to refer before, the complete and permanent destruction observed by Moore and Whitley is only apparent. Perhaps these authors tested their extracts *immediately* and *only* immediately after adding H_2S. At least we find no reference in their work if they did otherwise.

9. *Acidity of the cell sap and its function and significance.*

It has been already stated that the cane extract in the absence of chloroform deteriorates, and its activity increases on keeping. Thus a particular sample of the extract showed during 40 hours an increase in acidity about three times the original figure. This was accompanied with the disappearance of the usual oxidase reactions. We find that in some cases the removal of the acid generated on keeping the oxidase extract is sufficient to bring back the oxidase reactions, but in other cases the addition of hydrogen peroxide is necessary. This was found to be the case in the particular sample referred to above.

We have seen that the oxidases are extremely sensitive to the reactions of the cell sap. This sensitiveness is much more marked in the case of the enzymes; while in the case of any one particular enzyme a slight increase of acid may be favourable for its action, this same slight increase may become prejudicial to the other enzymes. The cell, if it were to have the power of controlling the amount of acid present in the sap, will possess a very effective mode of allowing only a particular kind of reaction or reactions to proceed at a certain time, while at some other time keeping these in obeyance and allowing other kind of reactions to go on. That it possesses this power of varying the acid concentration at different times of the day is shown by a couple of experiments performed by us. Two kinds of cane were selected, the longer fully grown up ones and the smaller ones not fully developed. Acidity on 100 grs. of wet and dry leaves in terms of c.c. of N/10 NaOH was found to be as follows:—

		Wet leaves	Sun-dried leaves
Fully developed canes	**Morning**	27·82	60·60
	Afternoon	16·72	40·10
Undeveloped canes	**Morning**	34·24	114·91
	Afternoon	8·93	21·41

Thus we find that in both the cases the acidity falls with the sun. This would mean that the oxidation processes are suspended in the morning, but have their full swing when the sun is highest, *i.e.*, they run parallel with the other photosynthetic processes.

In this connection mention may be made of the work of Petit.[1] It is known that barley contains an enzyme which saccharifies starch paste but does not liquefy it, the liquefying action being only developed on germination. The author, however, found that the same effect is produced by simply varying the acidity. Thus we see that a simple variation of the acidity contents of the reacting media conferred on barley diastase the power of liquefying starch paste.

10. *Starch potassium iodide test for oxidases and the presence of nitrites in the cell sap.*

Aso and more recently Wolff and de-Stoecklin have questioned the validity of starch potassium iodide reaction as a true test for the oxidases. They attribute this reaction to the presence of nitrous acid occurring in the plant extract.

Greiss's reaction is the only one best suited to test the presence of nitrous acid when it occurs in small amounts. This reaction when applied to the cane extract gave a coloration which was rather pinkish yellow than pink. It is doubtful whether on the basis of this reaction we are justified in assuming the presence of nitrites in our plant extract. However, taking for granted that this colour is due to nitrites, the next point is to decide whether this amount of the nitrite is sufficient to give the starch potassium iodide reaction. This can be done in two ways. The amount of nitrite in the extract may be estimated in terms of a known nitrite such as sodium nitrite ; and then a solution may be prepared that would contain as much sodium nitrite as has been found to be present in the extract. Now starch potassium iodide reaction may be applied to both of these solutions. If the reaction is carried to the same extent in both the cases then it would mean that the reaction is not a distinctive test for oxidases. The other method to test the point is to see whether the oxidase powder obtained by precipitation with alcohol from leaf extract gives the Greiss's test, and if so whether the starch potassium iodide reaction comes to the same extent as with a solution containing the corresponding amount of nitrite. The experiments performed as outlined above show distinctively that the amount of nitrite detected by Greiss's test is not sufficient to give the starch potassium iodide reaction. Hence we are justified in assuming that the greater part, if not the whole, of the reaction is due to the substance or a system of substances which we call "oxidases."

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[1] *Compt. rend.*, 1904, 138, pp. 1003-1004.

11. *The nature of oxidases : Are they enzymes ?*

Our conception of enzymes is associated with the possession by these of two fundamental properties : (*i*) destruction by heat, and (*ii*) the capacity of bringing about change in a practically speaking indefinite amount of substrate. In these two properties we have a criterion whereby to judge whether any substance is enzymic in character. It was by following this principle that Bayliss and Starling were able to demonstrate enterokinase to be a true enzyme. We have seen that the cane extract is extremely rich in the possession of a substance or substances termed oxidases capable of stimulating a number of oxidations. It has been almost tacitly assumed by a large number of workers that the oxidases are enzymic in character. And the assumption has been mainly based upon the fact that these bodies have been found to be sensitive towards heat. As to the second of the above properties, Jacoby's[1] is the only instance, who found that if the salicylic acid formed is removed by dialysis, the oxidase still possesses some activity. In direct contradiction to this, Medvedew[2] had observed that the oxidation of salicylic aldehyde to salicylic acid cannot be increased by an increase in the amount of oxygen present. It is difficult to reconcile Jacoby's results with this observation ; however, as pointed out by Kastle and Loevenhart, it is possible that the oxidases were present in very large quantities in Jacoby's solutions or those contained usually large amount of active intramolecular oxygen. Whatever may be, it cannot be said to have been definitel shown that oxidases are able to bring about change in an indefinite amount of the substrate.

Kastle and Loevenhart were the first who sounded a strong note of warning against regarding these substances as enzymes. The fact that a number of artificial oxidases have been prepared from time to time, which possess all the usual properties of oxidases, lends support to the suspicions of these workers as to the enzymic character of these bodies. Apart from their destruction by heat and a few poisons, but little is known concerning them which would lead us to regard them as of enzymic character. In fact they do not seem to act as oxygen carriers at all in the sense of being able to transform large amounts of oxygen from the air to the oxidizable substance. Again it seems never to have been satisfactorily established that they are real catalysts in the true sense. These doubts of Kastle and Loevenhart were confirmed by Euler[3] and Bolin who found that laccase is not of the enzyme type as it could be boiled for three minutes without destroying its activity. Doney-Henault[4] regards the oxidase action as catalytic but not diastatic, since it is variable or general and not specific.

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[1] *Zeitschr. f. Physiol. Chem.*, 1900, XXX, pp 135—148.

[2] Pflüger's Archiv., 74, p. 193.

[3] *Zeitschr. f. Physiol. Chem.*, 1908, LVII, pp. 80—98.

[4] *Bull. del'Acad. Roy. de Belg.*, 1907, pp. 537—638.

It is rather strange that in face of these facts, the oxidases up till now continue to be regarded by a large majority of workers as enzymic. Our own experiments on the effect of boiling show conclusively that the oxidases are not enzymic in the true sense of the term. It is said that the activity of the boiled extract returns on keeping owing to the formation of a fresh quantity of the enzyme from the zymogen more resistant to heat. It is doubtful, however, whether any zymogen can withstand the effect of vigorous boiling for 15 minutes, much less of a further boiling the once boiled and cooled juice for the same time again. Again, we have been able to obtain guaiacum reaction from extracts of cane leaves which have been dried in the steam oven for six hours. Even the ash of these leaves gives a faint but distinct reaction. These facts lend strong support to the assumption that the oxidases are in reality "compounds" of some inorganic substance with certain colloids, which colloids do not seem to be proteins as supposed by Bunzel.[1] Similarly it has not been proved that the oxidases are able to act upon a practically indefinite amount of substrate. The author performed a number of experiments to test this point, which are still in progress. Using the alcohol precipitated oxidase as the material to work with and measuring the amount of iodine liberated, it was found that the reaction comes to a standstill after a time, although there is still a large quantity of the undecomposed hydriodic acid present ; and shortly after this suspension of action, the opposite reaction due to reductase action begins and the amount of iodine liberated begins to be reabsorbed until no more of it is left. The problem involved in oxidase kinetics is too complex and requires more work for its elucidation.

However, the facts noticed by us, together with the observations of Euler and Bolin, Doney-Henault, and Kastle and Loevenhart, demonstrate clearly that these bodies are not enzymic in nature. In the face of such a mass of overwhelming negative evidence we are not justified in ascribing to these bodies properties which they do not possess.

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[1] *Journ. Bio. Chem.*, XXVIII, 1916.

RHIZOCTONIA IN JUTE: THE INHIBITING EFFECT OF POTASH MANURING.

BY

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In the course of an investigation into the manurial requirements of jute, *Corchorus* sp., which is being carried out at Dacca, some observations have been made, which seem to indicate a relationship between the incidence of *Rhizoctonia* in jute and the potash content of the soil. The results of the investigation, so far as they bear on this point, are presented in the following note in the hope that they may be of interest to the members of the Congress.

At Rajshahi on one occasion *Rhizoctonia* became epidemic in a seed crop of *C. olitorius*, which had to be cut in order to save it from destruction. At Dacca the disease became more serious each year up to 1916: it was especially liable to attack comparatively late-sown jute, such as pure lines which, as a precaution against loss through weather uncertainties, are not usually sown until there is no danger of damage from drought. So serious did the danger to the selection work on jute seem to be becoming that its removal from Dacca was considered. In 1916 in order to save the crop, extravagant manuring with cowdung and nitrate of potash was resorted to: this action had the desired effect and as the same thing had happened once before it was surmised that the attack might be due to malnutrition in the plant.

SOIL TYPES IN BENGAL.*

The soils of Bengal may be roughly classified into two widely differing main types, *viz.*—

(1) The old alluvium or laterite red soils.

(2) The new alluvium or river silt.

(1) *The old alluvium* forms a large and compact tract in Western Bengal, where it comprises large portions of the districts of Burdwan and Midnapore, and practically the whole of the districts of Birbhum and Bankura, bordering on the high lands of the Chota Nagpur plateau. Extending northwards it is found in the west of the Rajshahi District, whence it passes, like a broad red stream, into Bogra. Here it appears to divide, one branch known as the "Bahrind" tract, passing northwards into the Dinajpur and Rangpur districts, where it loses itself in the new alluvium, only to reappear in the Terai, in the north-east of the Rangpur District and in the adjoining portions of the Goalpara District of Assam. Returning to Bogra, the second branch passes eastwards, under the Jamuna or New Brahmaputra, into Mymensingh, where it reappears at Jamalpur and extends to the south-east, through the eastern portion of the Dacca District, and across the Meghna river, into Eastern Tipperah.

Broadly, the soils of this tract, though possibly not clays in the strict sense of the term, behave very like clay soils in that they become very sticky when wet and very hard when dry. They hold moisture badly so that they dry up rapidly; and cultivation is therefore very difficult and has to be concentrated into short intervals of time. Apart from their intractable nature, the red soils are very poor and are generally markedly deficient in both lime and phosphoric acid. Carbonate of lime is practically uniformly absent and the total lime content is often below 0·2 per cent. The phosphoric acid is often extraordinarily low, and samples have been examined in which the total phosphate is almost too small to be estimated. The percentage of total potash is about 0·3, which would not ordinarily be considered very deficient, and indeed does not appear to be so for other crops than jute.

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* A survey of the soils of the Province of Bengal is at present engaging practically the whole of the energies of the Agricultural Chemist and his staff.

The whole of the red soil tract is comparatively thinly populated in spite of the fact that it lies adjacent to—in the Dacca District, for instance—one of the most densely populated areas in India. In the Dacca and Mymensingh districts a considerable proportion of the red soil tract, known as the Madhupur jungle, is still under heavy sal (*Shorea robusta*) forest.

(2) *The new alluvium or silt.* These soils may be said to occupy the whole of the area in Bengal which is not included in the laterite. The silts vary greatly in composition ; but generally they exhibit the following characteristics :—

(*a*) They contain considerable quantities of lime (1 per cent. appears to be common), but little or no carbonate of calcium. In Western Bengal, however, and in isolated spots elsewhere, *e.g.*, in the Jessore District, from 3 per cent. to 4 per cent. of carbonate of lime is found.

(*b*) The potash content is normally high, and occasionally extraordinarily so, *e.g.*, in the Munshiganj Subdivision of the Dacca District, where the total potash approaches 2 per cent. Nevertheless, isolated areas containing little potash are to be found, *e.g.*, at Rajshahi in Western Bengal.

(*c*) Phosphoric acid is also present in sufficient or considerable quantities, and Mr. Davis, Indigo Research Chemist to the Government of India, informs me that phenomenally large amounts are occasionally found, as at Kotchandpur in the Jessore District and also in parts of the Terai.

Typical analyses of the two soil types are given below. The figures represent percentages soluble in hydrochloric acid (sp.gr. = 1·16) after 12 hours' digestion at 100°C.

	*Red soil (old alluvium) from high land of the Dacca Government Farm	River silt (new alluvium) from the Narayanganj Subdivision of the Dacca District
	%	%
Phosphoric acid P_2O_5	0·04	0·23
Potash K_2O	0·30	1·27
Lime CaO	0·18	0·92
Magnesia MgO	0·38	1·47

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* Analysis by Mr. A. A. Meggitt, now Government Agricultural Chemist, Assam.

There was no free carbonate of lime in either sample and the reaction of the red soil is acid.

Rhizoctonia is a genus of fungi of which representatives are to be found in every soil. Dr. Butler, Imperial Mycologist, classifies *Rhizoctonia* as a weak parasite, excepting under certain conditions, and experience with jute bears this out; for although isolated plants attacked by *Rhizoctonia* are commonly to be seen in the jute-growing tract, a serious epidemic, involving an appreciable proportion of any crop, has only been met with in certain tracts, such as the red soils of the Dacca District and, once, at the Rajshahi Farm.

The morphology and parasitism of *Rhizoctonia* has been studied by Shaw[1]: Shaw and Ajrekar[2] have also studied other forms of *Rhizoctonia* occurring in India. In the former paper Shaw concluded that *Rhizoctonia Solani* is the form which attacks jute (*Corchorus* spp.), and several other plants including sann-hemp (*Crotalaria juncea*), cotton (*Gossypium*, spp.), and Bimlipatam jute (*Hibiscus cannabinus*).

Rhizoctonia caused no trouble during the four years (1906-1909) in which the work on jute was carried on at Pusa (Bihar); but serious difficulty was at once experienced when the investigation was transferred to the red soil at Dacca in 1910. In the red soil tract it is the custom of cultivators not to sow jute on the same land oftener than two years in five, and it is considered that once in three years is safer still. On the other hand, on low-lying lands of the new alluvium, which the soil analyses quoted above show to be rich in potash, jute is often sown several years in succession.

MANURIAL EXPERIMENTS.

The first manurial experiments with jute at Dacca involved the use of the constituents which the soil analyses showed to be most deficient in red soils, *viz.*, lime and phosphate (East Shuti field experiments). The lime produced a remarkable effect, not only on jute and other *kharif* (monsoon) high land crops, but also on the *rabi* (cold weather) crops. An application of one ton per acre of lime increased the yield of jute fibre by about 300 lb. per acre : this is worth more than the cost of the lime, the application of which therefore gives a net gain in the first season. As the effect of the dressing lasts for about three years, the practice of liming proves a profitable one and will spread widely in the red soil tracts as soon as Co-operative Credit is sufficiently organized to develop it. The phosphates do not apparently influence the jute crop, either alone or in combination with lime ; nor did either lime, or phosphate, or the combination of these prevent a large number of plants from being attacked by *Rhizoctonia.* Nevertheless the results obtained were obviously good enough to encourage further investigation, and, in view of the acid nature of the soil, it was decided, in 1915, to ascertain how far more soluble and more drastic alkalis like the carbonates of soda and potash could reinforce the effect of lime. The whole experimental area (S. Mirpur field) received 30 maunds (about 1 ton) of slaked lime ; 3¾ cwt. (5 maunds) of ground rock phosphate, and 40 lb. of nitrogen, as castor cake, per acre. Out of six plots two received nothing in addition to the above ; two received 380 lb. carbonate of soda, and two plots received 500 lb. of carbonate of potash per acre.

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[1] Shaw, F. J. F. "Morphology and parasitism of *Rhizoctonia*." *Mem. Dept. Agric. India, Bot. Ser.*, IV, No. 6, 1912.

[2] Shaw, F. J. F., & Ajrekar, S. L. "The Genus *Rhizoctonia* in India." *Mem. Dept. Agric. India, Bot. Ser.*, VIII, No. 4, 1915.

The result was very surprising, as the carbonate of potash plots gave a mean yield of 33 maunds 28 seers (24 cwt.) of fibre per acre, a phenomenal yield for the poor soil of the Dacca Farm and one of the biggest crops ever recorded. The carbonate of soda plots yielded 27 maunds 35 seers (1 ton) of fibre per acre, nearly 6 maunds (4 cwt.) less than the return from the carbonate of potash plots and less than two maunds (1½ cwt.) better than the checks. Thus the effect of the carbonate of potash involved more than the mere neutralization of soil acidity.

More recent experiments with water hyacinth (*Eichornia crassipes*) have been described in a Pusa Bulletin,[1] which give further proof of the value of potash manures for jute on the red soils of Eastern Bengal. It is not necessary to discuss this matter further here; but it will be interesting to trace the history of the South Mirpur series last year (1916), and in the present year (1917).

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[1] "Water Hyacinth (*Eichornia crassipes*): Its value as a Fertilizer," by R. S. Finlow and K. McLean. *Agric. Res. Inst. Pusa Bull.* No. 71, 1917.

In 1916 it was decided to grow jute again on the plots in order to test the residual effect of the manures applied in 1915. Only a general manure (40 lb. of nitrogen per acre as castor cake) was applied; the season was a very bad one and a long drought in May 1916 permanently stunted the growth of the crop. The fields are given below and those for 1915 are included for purpose of comparison.

	1915		1916	
	Mds.	srs.	Mds.	srs.
Check (mean of duplicates)	27	35	11	2½
Carbonate of soda (mean of duplicates)	29	31	11	10
Carbonate of potash (mean of duplicates) ...	33	28	11	17

The yields in 1916 were thus, to all intents and purposes, identical.

In 1916 the Imperial Mycologist and the writer noticed that jute plots which had received potash, or the equivalent in water hyacinth, were freer, on the whole, from *Rhizoctonia* than those to which potash had not been applied. For instance, the potash plots in South Hazi field were not entirely *Rhizoctonia*-free; but there were, on the whole, considerably fewer affected plants in them than in other plots.

In order to throw further light on this important question, it was ultimately decided, as stated above, to sow jute again in 1917, for the third year in succession, in the potash series of plots in South Mirpur field. There was a twofold object in using this series. Firstly, it had been noticed that the oftener jute is sown in any given land the more liable the crop is to be seriously attacked with *Rhizoctonia*. An almost universal practice, which is the result of experience, exists among cultivators in the red soil tract, *i.e.*, not to sow the same land with jute oftener than twice in five years or, better still, once in three years. The series in question had already carried jute for two years, and 1917 being the third season, it was therefore highly probable that *Rhizoctonia* would appear with some severity unless prevented from doing so. Secondly, it was thought that the potash-treated plots would, if *Rhizoctonia* is associated with potash shortage, show a comparatively greater resistance to the incidence of the disease than the plots not treated with potash.

Before sowing, the whole of the series received the following manurial treatment :—

Castor cake	40 lb. nitrogen per acre.
Bonemeal	55 lb. phosphoric acid (P_2O_5) per acre.

In addition the two potash plots received the ash of water hyacinth in quantity containing 200 lb. potash (K_2O) per acre. This is equivalent to a dressing of 370 lb. ($4\frac{1}{2}$ mds. or $3\frac{1}{2}$ cwt.) of pure sulphate of potash per acre. The soda plots received 220 lb. per acre of carbonate of soda, equivalent to 130 lb. Na_2O per acre.

Sowing could not be done till the middle of May, which is very late, and the season was generally unfavourable. All the plots therefore suffered seriously, but the potash plots were, as the figures show, 100 per cent. better than the others.

Plot No.	Special treatment	Yield of fibre per acre	
		Mds.	Srs.
A & D	Carbonate of soda (130 lb. Na_2O per acre)	4	0
B & E	Checks	3	0
C & F	Hyacinth ash (200 lb. K_2O per acre)	8	20

Rhizoctonia was rampant throughout the non-potash plots, which always contained about ten times as many diseased plants as the potash plots.

Plot No.	Special treatment of plot	No. of diseased plants in portion of plot examined *	Approximate No. per acre	Approximate proportion of diseased plants
				%
(a)	Carbonate of soda	109	17,585	12·0
(b)	Nil	97	15,649	10·0
(c)	Hyacinth ash (200 lb. K_2O per acre)	12	1,933	1·3
(d)	Carbonate of soda	63	10,141	7·0
(e)	Nil	55	8,873	6·0
(f)	Hyacinth ash (200 lb. K_2O per acre)	6	968	0·6

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* These counts were made by Babu A. L. Som, Mycological Collector, Bengal Agricultural Department.

There is little more to say; but it is perhaps worth while to remark that a large number of plant ash analyses tend to support these indications of a connection between the incidence of *Rhizoctonia* and shortage of potash in the soil.

In collaboration with Dr. Butler an attempt is being made to extend this work in other directions and some suggestive results have been obtained.

THE SPRAYING OF TEA IN NORTH-EAST INDIA.

BY

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THE tea bush in common with other plants is subject to attacks of pests and blights. Although the appointment of special officers for their study has been comparatively recent, their treatment by spraying has been advocated in North-East India for more than twenty years. It is only recently, however, that the majority of planters have seriously considered it as a practical method for application on a large scale. The tea in North-East India is now being cultivated more intensively than formerly, and the losses due to pests and blights are in consequence receiving more attention. The occurrence of serious outbreaks of fungus disease in various districts has also emphasized the need for blight treatment on a large scale. In spite of the fact that from time to time experiments in spraying had been carried out on gardens, very little attempt had been made to adapt the machinery designed for use on other plants, and under different climates, to the special conditions found on tea gardens. The operations took up much time and attention. The amount of labour used was out of all proportion to the work done, and practical planters were justified in saying that spraying on a large scale was out of the question until improvements in machinery and organization had been made. The attention of this department was given primarily to effecting these improvements. Our department has not been able to do as much work on spray fluids as we had liked, as it was impossible to test them thoroughly until improvements in machinery and organization rendered spraying on a large scale feasible.

As many have not had the opportunity of visiting a tea garden, it is necessary, first of all, to give a brief description of the manner in which tea is grown. The plants are usually grown from seed in a nursery and planted out when they are from 6 to 18 months old. They yield their first crop about the third year from seed, but do not reach their optimum yield for six or more years. The plants are pruned according to system with the idea of keeping the tops of the bush wide and of uniform height. The bushes are planted in regular lines, $4' \times 4'$, $4\frac{1}{2}' \times 4\frac{1}{2}'$, $5' \times 5'$, either square or triangular planting. The plants usually touch each other when well grown. At intervals, sometimes irregularly, shade trees are often grown. The ground is often irregular and cut up by open drains and nullahs. In some districts very steep slopes are planted, sometimes without terraces. As a general rule the use of large, wheeled machines is impossible. The tea is pruned in the cold season and plucked in the rains. The plucking of each bush takes place every few days. In the hotter districts, in the height of the growing season, it may be necessary to pluck every five or six days, while in the hills a fortnight or three weeks may suffice.

The climate of the tea districts varies in the different districts ; but in all the cold season is practically rainless, and there are two rainy periods—one in May or June, the other in July or August. From April to September there are showers almost every day.

On tea gardens spraying may be used for two things :—

(1) To increase the yield by lessening the attacks of those minor pests and blights which are generally present even on well-kept gardens.

(2) To deal with outbreaks of more serious diseases.

For the first purpose, it is desirable to add spraying to the general routine of tea culture. To obtain the maximum benefit from this treatment, it is necessary to consider the life-histories of the pests and blights concerned. Comparatively few can be dealt with satisfactorily by spraying in the cold weather. Besides, much of the tea in many districts is so severely pruned that general spraying is hardly necessary. It would pay much better to search for and remove or treat all diseased leaves and twigs. A number of planters spray their pruned tea in the cold season with caustic washes to remove epiphytic organisms such as lichens. Some claim that this spraying is very beneficial. It would certainly be so in the colder districts, such as Darjeeling, where the lichens grow in profusion on the tea stems, harbouring many undesirable things. We have found by experiments, however, that solutions more caustic than 2 per cent. caustic soda are distinctly harmful to the tea plant. The best time to carry out general spraying is just before the first rainy period, and again in the less rainy weather which usually precedes the second period of heavy rainfall. During these periods the pests and blights are generally active and may check the growth of the tea most seriously. The heavy showers at other times in the rainy season interfere with the work so much that it is inadvisable to spray then, except in special cases, such as outbreaks of a serious epidemic disease.

The treatment by spraying of an outbreak of epidemic disease which has spread over a large area is at present practically impossible in the rainy season. The nature of the growth of the tea plant renders it impossible to prevent, by spraying, diseases attacking the young leaf, as the young shoots are constantly forming, and it would be necessary to spray about once a week. It would further be undesirable to spray the tea just before plucking, as the quality may be interfered with by the spray substances adhering to the leaf taken for manufacture. Before the young leaf is plucked a fresh growth of shoots has often commenced. To prevent the infection of this, it would be often necessary to spray before plucking. Preventive spraying at certain times of the year would therefore seriously interfere with tea culture. The only thing possible therefore is to watch for outbreaks and treat them when they occur. Unfortunately in some districts the gardens adjoin, and unless combined effort be made the disease or pest will be harboured on gardens on which no care is taken. This combination is not easily obtained, as all gardens are not affected to the same degree by the same disease, and an expenditure on the treatment of a particular disease, which may be reasonable on one garden, may be unwarranted on the neighbouring one. Combined co-operative effort is essential to success in the treatment of some diseases, and we have attempted to get the planters in Darjeeling to carry it out. The scheme put forward was briefly as follows : A permanent spraying brigade, like a fire brigade, would be established in each district. The machinery, etc., would be housed in a central place under the charge of a competent Indian mechanic, who should be capable of keeping records, etc., in English, assisted by a number of sirdars, a sirdar being allotted for every 400 or 500 acres of tea. Whenever an outbreak of blight be reported, a company with sufficient equipment would proceed at once to the place. The mechanic in charge would arrange the details, such as water-supply, manufacture of solutions, etc., the actual spraying being done by gangs of coolies supplied by the management of the garden on which the outbreak has occurred, under the supervision of the sirdars. Whenever the brigade was not actually engaged in spraying, the staff would be at work systematically searching for outbreaks. The financial arrangements for this work would involve a deposit according to acreage towards capital expenditure and an advance for revenue expenditure. The spraying would be charged for at so much per acre, the price being sufficient to cover expenditure and provide a small interest on capital deposit. In this manner it would be possible to adjust the financial arrangements, so that gardens which are least affected by blights would have least to pay for their treatment.

The Darjeeling Planters' Association discussed the proposal fully and appointed a Sub-Committee to take active steps. This sub-committee proposed to test the efficiency of the blight brigade idea on an isolated garden, and if it proved successful, to extend it to a group of gardens, and so on. Unfortunately the war has made it impossible to carry out this so far, but the matter is not being dropped.

Although no large combined effort has yet been made, many gardens are adding spraying to their general routine, and many more have only been deterred from doing so by the difficulty and expense of obtaining suitable machinery during the war.

A description of the spraying machinery and fluids employed on tea gardens may be useful to some who have to face similar problems.

Two types of sprayer have been used on tea gardens :—

(1) A heavy apparatus, forcing the fluid from a barrel to the nozzle through long flexible tubes.

(2) A light apparatus, carried on the back like a knapsack.

Our experiments have shown that the latter is more satisfactory. The long tubes of the barrel type damage the tea bushes, hinder the operators, and prevent their spraying the plants thoroughly. The apparatus is cumbersome, and more labour is required to do a given area in a given time than with machines of the knapsack type. All our attention has been devoted therefore to the latter.

Knapsack sprayers are of two kinds :—

(1) Those requiring continuous pumping.

(2) Those operated by a charge of compressed air.

Sprayers of the continuous pumping type have great drawbacks :—

(1) The attention of the operator is divided between the pumping and the direction of the spray jets. This is very undesirable.

(2) The operator is quickly tired, as he usually does much more pumping than is necessary to maintain the pressure.

(3) The working parts are small and hence delicate.

The compressed air type of sprayers has none of these drawbacks, and experiment has proved that it is the most useful type at present on the market.

There are two kinds of compressed air sprayers :—

(1) Self-contained, having an air pump fixed to the machine.

(2) With no pump attached, charged by a separate pump.

For spraying on a small scale the first kind recommends itself, as it is very handy. In choosing such machines, preference should be given to those having pumps of a comparatively large diameter, as they take less time to pump up.

For spraying on a large scale much time is saved by having machines without pumps attached and charging them from a single larger, powerful pump which may be used with a number of machines. Lately a further improvement has been devised. The latest machines are charged with air to a low pressure at the commencement of the operation only. The air is then further compressed by pumping in the spray fluid. The outlet is closed by a floating ball-valve which prevents the charge of air escaping. To recharge the machine with spray fluid it is merely necessary to pump in more spray fluid—no more air is required. This reduces the labour considerably, as in practice it takes much less time to charge with liquid than with air. This kind of machine is extremely simple. There is nothing on the knapsack portion likely to be spoiled by rough handling. The pumps are large and strong, and as there is only one set of pumps to a number of machines, a thoroughly capable man should be put in charge of them.

The nozzle is of great importance. Most of the modern nozzles produce the spray by giving the fluid a rotary motion. They differ principally in the means by which clogging is prevented. We have found that complicated nozzles with joints, springs, etc., are of no use, as they frequently go wrong and the coolies are not intelligent enough to put them right.

As it is important that the undersides of the leaves and twigs be sprayed, it is necessary to spray upwards as well as downwards. As this necessitates the nozzle being held close to the branches, it is important that the spray be produced as close to the aperture as possible.

The nozzles are generally used singly, attached to a brass tube about two feet long. The tube is often bent near the nozzle to facilitate the spraying of the undersides of the leaves and stems. With the single nozzle much depends on the good will and ability of the operator. The direction of the jet requires constant attention, and unless the work is supervised thoroughly well, the bushes will not be sprayed properly. A considerable improvement has been brought about by using a number of nozzles so arranged that the direction of the jet is automatic, and all the cooly requires to do is to carry the machines down between the lines of tea, holding the nozzle attachment in front of him. We find four nozzles do this quite well. Very little more solution is required per acre than with the single nozzle, and the work is done more thoroughly. It has been found by experiment that it saves two-thirds of the labour.

The organization of the work has been paid a good deal of attention. The spraying machines required to be supplied with liquid. In most cases the spray fluids are supplied to the field in concentrated form, and diluted there with water from neighbouring nullahs or wells. In hill districts it is often possible to lead the water to convenient places, but in some cases water has to be carried considerable distances. It is important that the supply of spray fluids be so arranged that there is no unnecessary walking about. For instance, the number of bushes a machine can do with one filling may be ascertained by a preliminary experiment. Then, if an operator with a fully charged machine starts at the beginning of a row, and turns back down the next row when he has sprayed half the number of bushes the charge will spray, his machine will be empty when he is only one row away from his starting point; if the charging apparatus be conveniently placed, he may never have to walk more than a few steps to get his machine recharged. In this way it is possible to reduce the labour considerably, as the operators of the spraying machines are wasting the minimum of time in carrying their machines to and fro for charging.

The question of spray fluids most suitable for use on tea gardens is complicated by the fact that the leaves of the tea plant are used for human consumption. It is obviously undesirable to use anything poisonous to human beings as a spray fluid. Arsenical preparations cannot be employed, although copper solutions are quite harmless, as the amount of copper contained in a cup of tea made from leaf sprayed with them is found to be too small for detection by ordinary methods and quite harmless. Our experience has shown that it is impossible to get solutions requiring accurate measurements and careful preparation made satisfactorily on tea gardens. We are therefore devoting special attention to ready-made preparations.

This year we tested a number of these, and our observations showed that lime-sulphur solutions were on the whole the most satisfactory, both as fungicides and insecticides. They are very easy to use and not likely to cause such troubles as clogging nozzles. Fluids which contain solid particles or emulsions which require stirring are not advisable, for unless the supervision is very good, the coolies will not keep them stirred when charging the machines, with the result that some machines get more concentrated fluid than others.

In spraying operations carried out on tea gardens simplicity is essential. Nothing must be left to the good will and intelligence of the cooly. The only machines likely to prove useful are those which require no special attention. The manager of a large tea estate has so many things to attend to that he cannot spare the time to supervise any one set of operations personally during the whole time those operations are being carried out.

Lately some attention has been paid to dry dusting powders. We have not had much success with them so far, but if suitable powder can be invented, this is by far the most economical form of spraying. We have tried various forms of "Bordeaux" powders and mixtures of slaked lime and flowers of sulphur. The latter seem to be more satisfactory than the more expensive powders containing copper compounds.

SOME FACTORS AFFECTING THE EFFICIENCY IN THE USE OF CANAL WATER.

BY

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THE Punjab is pre-eminent with regard to the amount and scale on which crop production is dependent on large Government canals. Of the total irrigated area of 22,000,000 acres, over 9,000,000 acres are irrigated from canals. In the greater part of this canal area the annual rainfall is from 5″ to 12″ and the water table is from 20 to 80 feet below ground level. The soil is alluvium, and may be classed as sandy loam, though a good deal of variation occurs. Crops are thus, especially in winter, almost entirely dependent on irrigation for their water-supply. The canals are perennial ; but as the river supply in winter is low the quantity of water carried in the canals in that season is subject to very wide variations which cannot be altogether foreseen. Thus, in the Lower Chenab Canal the normal full supply is 10,000 cusecs, but in 1916-17 the discharge was at one time under 4,000 cusecs. At present five big canals are linked together, *viz.*, the Upper and Lower Jhelum, the Upper and Lower Chenab, and the Lower Bari Doab, and these are mainly dependent on supplies in the Jhelum and Chenab rivers. The river supplies drop sometimes rapidly in October and November, and render it difficult to get the full area under wheat which is the main crop of the Punjab canals. The critical period is during October and November.

especially during the latter month, as on the water then available will depend the area sown. With the full area sown, the problem is to utilize the canal supply to the full in maturing the crop.

The system of water distribution and the orders regulating it, with a view to making the best possible use of the water, are admirable, and reflect great credit on the Irrigation Department. The main principles of these are given below :—

1. The supply of water is given on a basis of 75 per cent. (in some cases 66 per cent.) irrigation per annum, *i.e.*, 50 per cent. of the land to be cropped in the *rabi* (winter) and 25 per cent. in the *kharif* (summer). This is all the Irrigation Department guarantee. In practice on most canals the cropping is 100 per cent., and often more.

2. When river supplies are low, the canals and their various branches are run in rotation, so as to keep them as full as possible. This prevents excessive proportionate losses by seepage and enables all the area to be commanded in rotation.

3. The water is divided up from main canals to branches, minors, and distributaries. The supply for the cultivators is generally carried by a water-course from the latter. Water-courses carry about 1½ cusecs ; which quantity, it has been found, can be handled most economically by the cultivator.

4. The land is divided up into squares of 25 units. (Sometimes these units are *killas* [a *killa* = 1·1 acres], but in the latest canals the square is 25 acres.) Each unit or acre has to be divided into 8 compartments, or *kiaris*, in direct contact with a water-course. There must be a water-course on either side of the acre unit to ensure water being taken direct into the *kiari*. Roughly, a water-course carrying 1½ cusecs commands 400 acres. Cultivators irrigate by turns of three hours, or *pahars*, based on the area, and in such a way that if the canal is running continuously each holder of a square or half a square gets his turn every 10 or 12 days. This regulation enables a cultivator to irrigate when necessary, and does not force him to irrigate prematurely, as would be the case if the turn, or *wár*, took much longer than 10 days. This is a very important point, especially in the *kharif* season.

It will be convenient if we discuss the present sources of loss or inefficiency under three heads, *viz* :—

I. Losses due to the nature or construction of the canals.
II. Losses by inefficient distribution.
III. Losses in the field.

I. The canals generally flow along the ridge of the *doab*, or tract between two rivers. Seepage through the sandy bed is enormous and constitutes the chief source of loss. Kennedy estimated the loss by seepage in the main canals and branches as 33 per cent. of the water entering the canal, while another 33 per cent. was lost in distributaries and water-courses, leaving only 33 per cent. for the field. These figures are perhaps excessive, but it is generally believed that at least 50 per cent. of the water is lost before it is applied to the field. This problem is mainly an engineering one, and the present regulations with regard to running the canals full, avoiding silting and scouring, etc., have been evolved to minimize these losses. Of late some work has been done by way of " lining " canals to prevent seepage and water-logging, the latter having become acute in places.[1] When considered from the point of view of the real value of the cusec, " lining " appears to be a very paying proposition, and, though a great deal of work remains to be done before it can be properly decided what material to use, it is certain the future must show development in this direction. What is wanted at present is concentration of experiments on one canal and the setting of the chemical or physical research work on a permanent basis.

Another source of loss, which is connected with the design of a canal, is dependent on the intensity of irrigation proposed. If the intensity is low the proportion of losses in channels becomes excessive, and the canal as a whole, in consequence, less efficient than if the water were concentrated on a smaller area. Some evidence on this point has recently been brought forward by Gibbs in a private communication.

II. The second main source of loss, while mainly concerning the Irrigation Department, also touches on revenue and agricultural aspects. The system of distribution and the rules with regard to *khal kiari* represent the practical results of Kennedy's and other Irrigation officers' work in this branch. The most recent work of importance in this line has been that of Mr. A. S. Gibbs, who has brought out several papers on the subject within the Department. It is a great pity they have not been given wider publication. The main tendency of late has been to concentrate on equable distribution either by use of Kennedy's " outlet " or a " module," such as Gibbs' module. The importance of this aspect of the question may be gauged from Gibbs' figures in one of his papers, where on the Lower Chenab the allotted area per cusec varied from 380 to 180 acres and the efficiency of irrigation from 100 per cent. to 67 per cent. The difference between the efficiency of various classes of cultivators was in the region of 9 per cent. as a maximum. These results are very instructive, but a great deal more work is necessary: for in cases where the allotted area per cusec is small the cropping will be different, and crops requiring a large amount of water, *e.g.*, sugarcane and *senji* (*Melilotus indica*), would be largely grown. The value of the return per acre will be similarly affected.

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[1] *See* Paper on " Cost of lining canals," by Curry, Punjab Irrigation Congress, 1917.

III. The third main source of loss, *i.e.*, by irrigators and in the field, is the most difficult to control, and by far the most complicated part of the problem, since many factors are involved. In the first place, it is not always easy to define what constitutes a loss and what constitutes a saving. For instance, it is roughly realized by Irrigation officers and many cultivators that some part (though by no means all) of the wheat crop of this province could be brought to maturity with a fair return, sometimes even a maximum return, by the application of only two waterings after sowing, *i.e.*, one in February and one in March. Even one of these may in some years be replaced by rain. This has been more definitely shown by various experiments.

The experiments conducted by the Irrigation Department have led to three waterings, after sowing, in the absence of rain, being accepted as more or less the standard all-round figure for the Punjab canals. For a rough, but safe and widely applicable, generalization, this is shown by experience to be the right figure. Experiments[1] and experience at Lyallpur have led to the conclusion that two well-timed waterings, with good cultivation and harrowing, as above, will suffice an average land in some years in favouring circumstances; but not otherwise. An experiment conducted by Rai Sahib Sewak Ram at Gangapur[2] has shown that on very good land, well cultivated and harrowed, a moderate crop was obtained with only one watering assisted by very timely rain in March. These results cannot, however, be regarded as applicable to all lands; for on many fields an earlier watering becomes absolutely necessary to protect the wheat against white ants or *kallar*. None the less, there are undoubtedly cases in which zemindars, having the water available, do apply it to wheat crops in December and January, when a fair, if not a maximum, crop could be grown without it. But supposing that by not doing so a watering is "saved"; nothing has been achieved unless this water can be put to some more profitable use. This is a much more difficult problem; for the only obvious way in which it could be profitably used is on a leguminous winter crop (such as *senji* or *shaftal**) grown for fodder or green manure. But such a crop would have to be sown in October and November, just at the time when water is most badly needed. Thus, rather paradoxically, the problem of using any surplus January water becomes a problem of saving water earlier at the critical sowing time. The matter is further complicated by the extreme uncertainty of the January supply.

Another way in which the Punjab Agricultural Department has shown that water can be saved, possibly with benefit to the crop, is by delaying the first watering to American cotton or to early sown country cotton. Full experimental data are not yet available; but crops of cotton sown in lines have been maintained by repeated interculture in a thoroughly healthy condition until June or even July without watering, and have subsequently given yields well above the average. This is sufficient to indicate at least a possibility of water saving in this direction. Again, however, it cannot be said that a saving has been effected until profitable use is made of the water. But in this case the problem is not quite so difficult, as sugarcane and fodder crops at this time make considerable demands on the water-supply, whilst any spare water could be profitably used for the breaking of fallow lands, or the growing of leguminous crops for produce or green-manuring.

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[1] *Experiments, etc., at the Agricultural Station, Lyallpur, Punjab.*

[2] Howard, A., and Howard, G. L. C. "Report of the Imperial Economic Botanists." *Scientific Reports of the Agric. Res. Inst., Pusa,* 1916-17, p. 31.

* *Trifolium resupinatum.*

In the areas irrigated by Government canals such as those of the Punjab, there is one enormous advantage in the hand of the would-be recommender of "water-saving" methods, *i.e.*, methods by which the water can be more efficiently used. This advantage lies in the fact that if the recommendations are really sound and the recommender is really convinced of their soundness, he has not to face the necessity of convincing thousands of cultivators of the truth of his remarks: he has only to convince the Irrigation Department and other Government officials concerned, as to the wisdom of the recommendations and to indicate exactly the advantages to be gained. A large-scale experiment can be initiated, and in the event of success the Irrigation Department should be able in time so to modify their system or regulations regarding supply, as to render the desired changes profitable to the cultivator, and thus ensure their adoption. Nor need there be any hesitation in making such a change if the case for it is sound, for the existing systems have not, as in many parts of India, been adapted in the course of centuries to the natural conditions or to almost equally stable economic ones. The system of agriculture followed under canal irrigation is one worked out by the cultivator in less than a generation to suit the amount of land and water given him and to meet newly arisen economic conditions; and so long as any further change is really sound, *i.e.*, really to the cultivator's benefit, he will not long maintain any objection to it. Moreover, new canals can be designed in accordance with the most up-to-date knowledge.

But this same facility by which improvements could be introduced lays a great responsibility on experimenters and upon Government, to see to it that all the effects of any proposed change, the limits of its applicability, and its real exact value, are completely worked out before any action is taken. For instance, it has been pointed out above that there is a possibility of saving a certain, but as yet very indefinite, amount of water in the mid-*rabi* season. But our experience at Lyallpur has equally shown that this by no means applies to all land. And to work out the limits of the applicability of this is infinitely more difficult than demonstrating that it can be done in some cases. The extent to which it applies can only be ascertained by very detailed investigation and thorough soil surveying. But, again, this water when "saved" represents a "gross" saving ; there are some debit items which have to be considered and worked out.

To withhold water from a field which by moderate cropping and very good cultivation has been brought into and maintained in a really good tilth, is a very different matter from withholding it from a crop growing on land which, from heavy cropping and less expensive cultivation, is not in such good order. Thus the " saving " costs something in fallowing and cultivation. This opens another broad field for investigation which is as yet untouched. Again, there is evidence that what applies to a late sown crop does not necessarily apply equally to an early sown one ; and thus, again, the effects of early and late sowing on the subsequent water requirements of the crop must be considered and investigated. This is a matter of much importance, for in most years the length of the sowing period is considerable, and there is a possibility of it becoming even longer in the future.

Another somewhat similar factor, which also has to be considered and possibly to some extent investigated, arises from the fact that all fields cannot be irrigated at the same optimum times, and an irrigator often wisely applies water earlier than would otherwise be necessary simply for this reason. The problems connected with making a profitable use of such water when it has been " saved," have already been touched upon.

Very similar, though somewhat less difficult, factors arise out of the water-saving in regard to cotton in the early stages, of which we have already indicated the possibility.

It will thus be seen that very extended and detailed investigation is necessary before we can widely translate into practice even very simple principles which have been realized and explained by the Agricultural Department for some years and are already somewhat recognized outside.

These are the problems involved in making the best possible use of the present canal supply, if this be accepted as unalterable. But the supply available for irrigation would be greatly increased if any great extent of the canals and branches were lined. Moreover, there is always much water running uselessly down the rivers in the summer, some of which might possibly be taken into the present canal areas by enlarged and lined canals. For the working out of the economic results of any possible change in this direction we need much more data than are yet available ; and it would involve the study of systems of more intensive agriculture than those yet followed, together, probably, with a change in the direction of more stock-rearing.

It will thus be seen that the problems involved in making the most efficient use of the water-supplies in our Punjab rivers are very broad, and much bigger than those with which Agricultural Departments have generally been concerned.

The agricultural investigator usually has little power to vary any of the great factors governing the agricultural practices—such factors as the value of land, the water-supply, the temperatures, and the cost of labour being beyond control. In these irrigated tracts we can control the water-supply within considerable limits ; this puts the value of the land under some control, and even gives us some choice in the matter of temperature, since to some extent there is a choice between *kharif* and *rabi* cropping. And in view of the great capital value of the canals and their enormous effects, present and potential, on the prosperity of the province, the problems involved are well worthy of adequate and early investigation and real research.

THE PHYSICAL TEXTURE OF SOILS IN ITS RELATION TO CROP PRODUCTION.

BY

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It has been said that "No industry is so profitable or yields such abundant returns in proportion to labour expended as agriculture : for the work is done by natural forces ; all that man has to do is to supply the conditions and give the powers of Nature free scope. It is very different from manufacture, where every rivet has to be hammered into place and every finish attended to by labour and design. In growing crops the main work and all the design is carried out for us. Wherever there is sun and air and any kind of soil, there crops can be grown ; for fertility of soil is largely a matter of treatment."

The tendency in the Central Provinces and other parts of India where agriculture is backward is to rely on the existing fertility of the soil, to reduce the amount of treatment given to a minimum, and to allow areas of so-called inferior soils which do not respond to careless methods of treatment to remain uncultivated. In the Central Provinces there are large areas of lateritic soil most of which is lying waste at present and which is considered to be below the margin of profitable cultivation. Small areas of this soil brought under cultivation are cropped with *kodo* (*Paspalum scrobiculatum*), one of the most inferior crops grown in the Provinces. This lateritic soil is locally known as *bhata*, and its purchase value is from Rs. 3 to 3-8 per acre. This *bhata* is of a coarse, gravelly texture, and the mechanical analysis shows it to contain 69 per cent. of gravel and stones and only 31 per cent. of fine soil, as against 4 and 96 per cent. of gravel and fine soil, respectively, for black cotton soil. The enormous possibilities of this lateritic soil have only lately come to light as the result of the opening of a Government Farm at Chandkhuri, the soil of which is nearly all pure *bhata*. A small part of the farm area consists of rather heavy soil (a clayey loam) known locally as *dorsa*. The results of the mechanical and chemical analyses of both these soils are given in Table I.

TABLE I.

Showing the mechanical and chemical analyses of bhata *and* dorsa *soils of Chandkhuri Farm, Raipur.*

	Bhata soil	Dorsa soil
Stones and gravel	69·00	11·40
Coarse sand	9·88	5·09
Fine sand	5·22	4·03
Silt	4·95	20·31
Fine silt	3·63	18·71
Clay	4·60	31·11
Moisture	0·68	4·38
Loss on ignition	2·04	5·56
Carbonates	0·08	0·11
	100·08	100·70
Nitrogen	0·025	0·056
Phosphoric acid total	0·048	0·011
Available do	0·007	traces
Total potash	0·527	0·910
Available potash	0·080	0·110
Calcium carbonate	0·080	0·110
Organic carbon	0·159	0·200

PLATE VI.

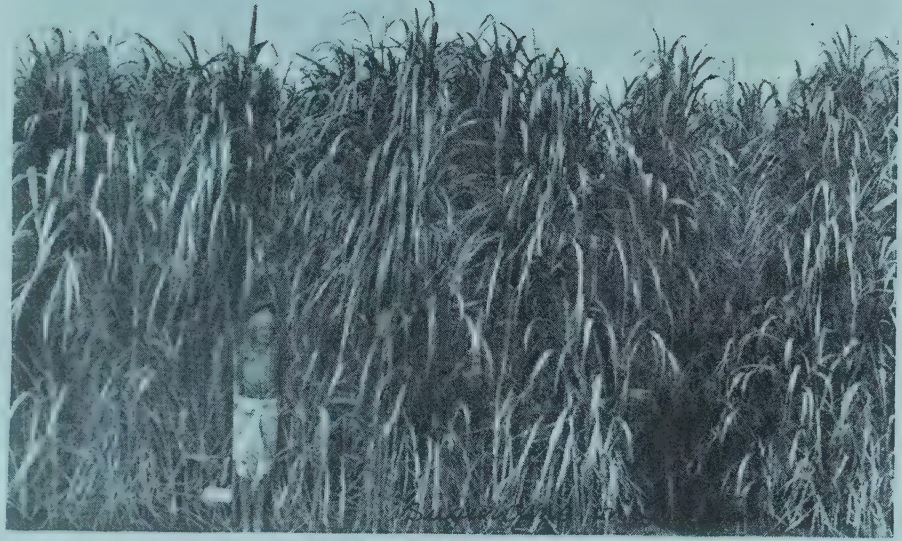
Fig. 1, SUGARCANE ON BHATA.

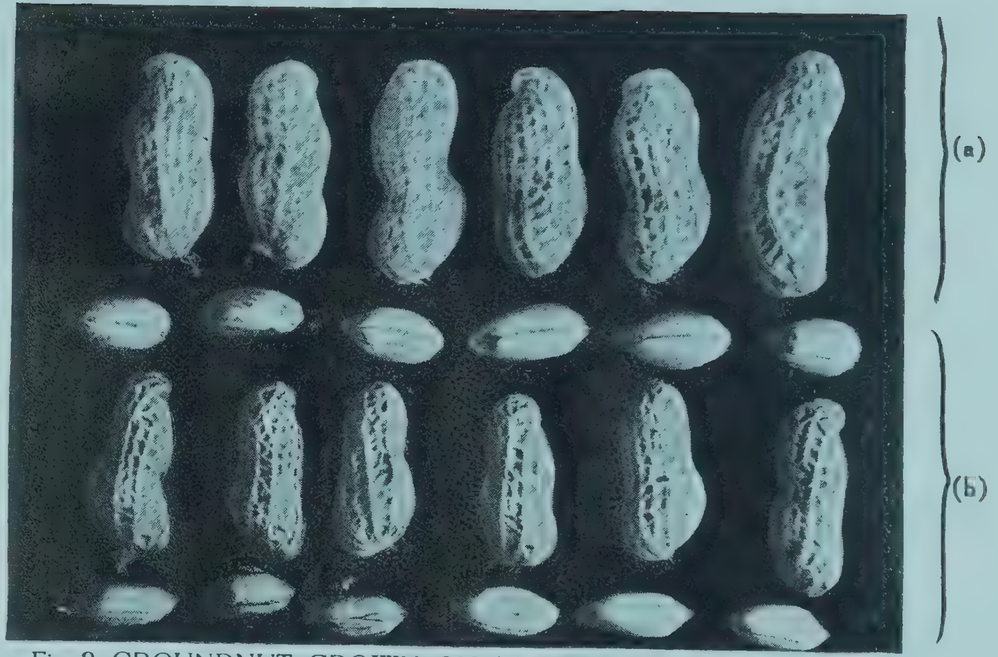

Fig. 2. GROUNDNUT GROWN ON (a) BHATA, (b) BLACK SOIL.

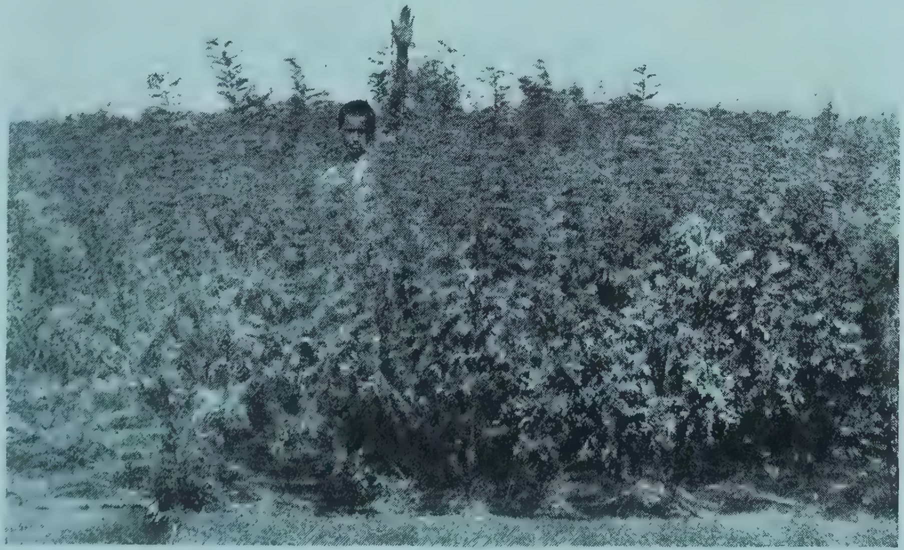
Fig. 3. INDIGO ON BHATA.

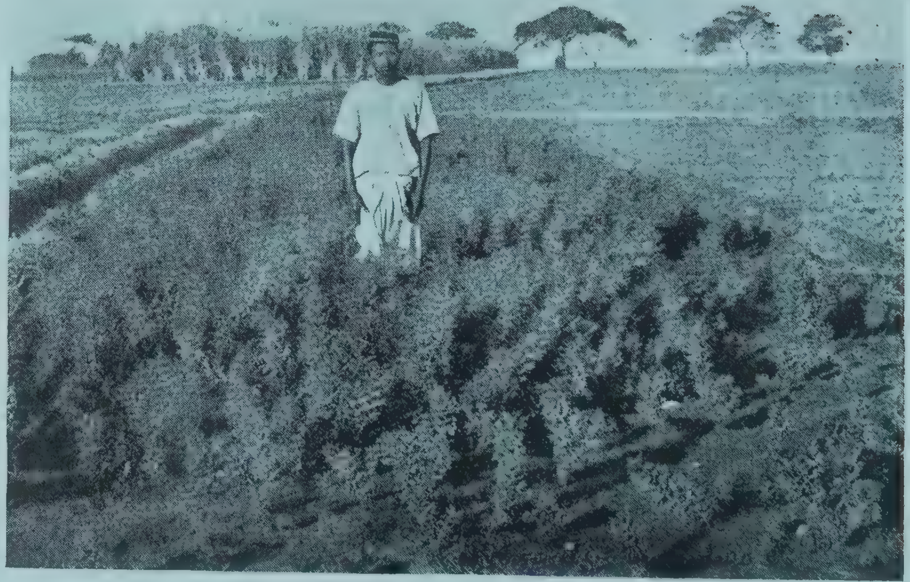
Fig. 4. INDIGO ON BLACK SOIL.

From the table it will be seen that *bhata* soil is poorer in nitrogen, phosphoric acid, and lime than *dorsa* soil. The biological analysis of *bhata* shows that, though it has been lying waste for an indefinitely long period, it has got the necessary mycroflora required for the decomposition of the organic manure added. The ammonifying capacity of this soil is quite good : the nitrifying power, though not so good as that of black soil, is also fairly good considering the fact that it has never been manured or cultivated.

Bhata readily responds to manuring and irrigation and will be much improved by cultivation. This fact has already been brought to light from the field experiments carried out at Chandkhuri Farm where, with irrigation, this soil has given under agricultural treatment much larger yields than black soil. This is due almost entirely to the fact that the soil is porous. Its porosity ensures good drainage, good aeration, and oxidation, conditions of special advantage to nitrification. These conditions are not met with to anything like the same extent in our richer but heavier classes of soil.

Manure applied under these conditions is utilized to the best possible advantage. Given irrigation and manure, we have in such a soil all the conditions which make for the healthy development of the plant. Plate VI, fig. 1 shows a crop of cane grown on *bhata* which yielded over 40 tons of stripped cane per acre. This class of soil produces not only larger crops of cane, but cane which is entirely free of red rot, to which this crop is so subject when grown on the less well-aerated and well-drained black soils.

Groundnut has done equally well, out-turns of 2,400 lb. per acre having been obtained from plots manured with basic slag. The actual acreage out-turn of groundnut grown on *bhata* is nearly twice as great as that ordinarily obtained from the richer but less porous black soil. Plate VI, fig. 2 shows the relative sizes of the same variety grown on *bhata* and black soil in the same district.

Plate VI, fig. 3 shows a field of indigo grown this year on *bhata* soil on the Chandkhuri Farm. The plants have not only grown to a satisfactory height, but they have produced a good yield of seed. On the black cotton soil on the Tharsa Farm the same crop is less promising, as Plate VI, fig. 4 shows. Here, again, we attribute the difference to better aeration in the *bhata*, for the climatic conditions do not differ to any extent on the two farms.

The average acreage out-turn of *deshi* cotton on black soil in the cotton tract last year was approximately 180 lb. of *kapas* (unginned cotton) per acre : it will be less by about 20 lb. of *kapas* this year. The low out-turn of last year was due to the heavy and continuous rainfall in August and September ; while this year the poorness of the crop is due to the excessive rainfall in the last half of September and the early part of October. Cotton grown on *bhata* on the Chandkhuri Farm (Plate VII, fig. 1) did not suffer last year; as may be gathered from the fact that Cambodia yielded 783 lb. of *kapas* per acre and the crop is almost equally good this year. We have then, in *bhata*, a soil which is well aerated and drained throughout the year and which under irrigation is independent of the vagaries of the rainfall.

Plate VII, fig. 2 shows a crop of *juar* (*A. Sorghum*) grown in a small area of black soil on the Chandkhuri Farm. The crop looked pale and yellow during the rains, due evidently to nitrogen-starvation on this richer but heavier soil. Plate VII, fig. 3 shows a crop of *juar* grown the same year in an adjoining *bhata* field on the same farm. This crop was not only of a healthier colour but grew to a much greater height.

In India there are many millions of acres of waste land of this lateritic soil known under different names, but all possessing the qualities which make for the healthy growth of our most profitable crops. In the Central Provinces alone there are about 1¼ million acres of cleared and partly cultivated land of this class, in addition to a still larger area of the same soil at present classed as "jungle and waste land."

How far these can be utilized for this purpose will depend on the irrigation facilities available. It is worth while considering

PLATE VII.

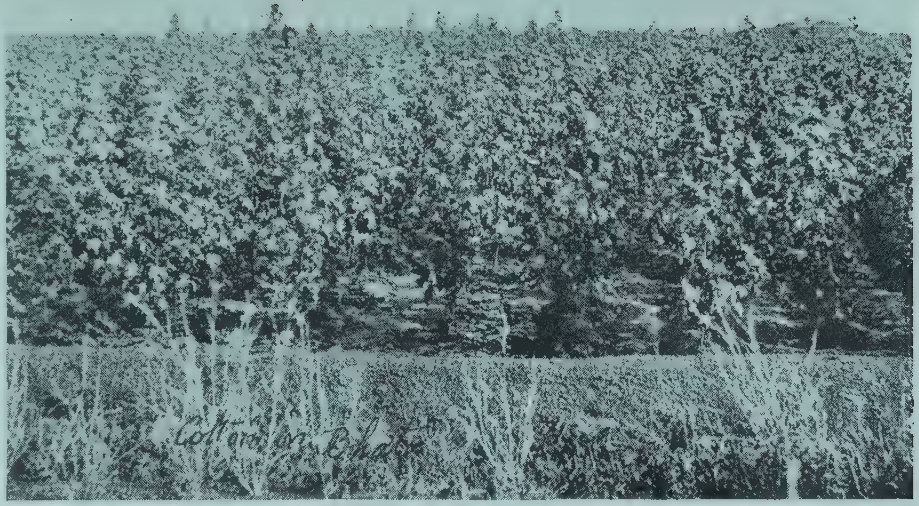

Fig. 1. COTTON ON BHATA.

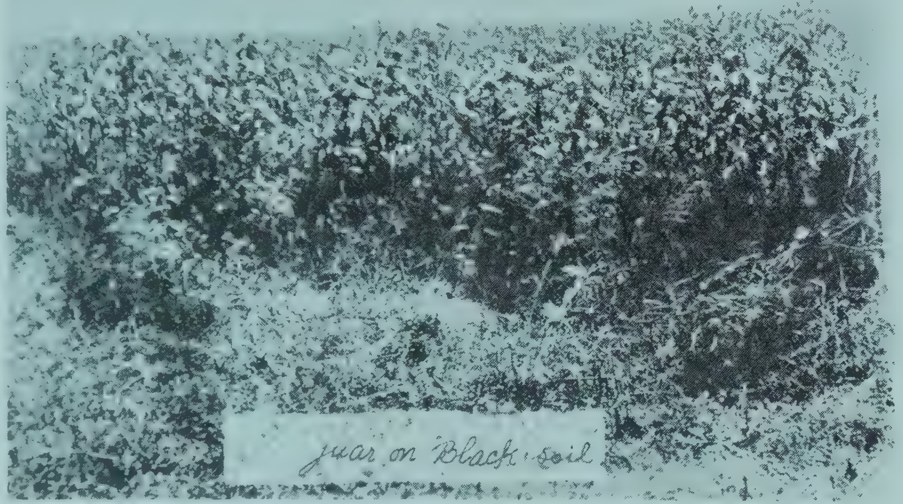

Fig. 2. JUAR ON BLACK SOIL.

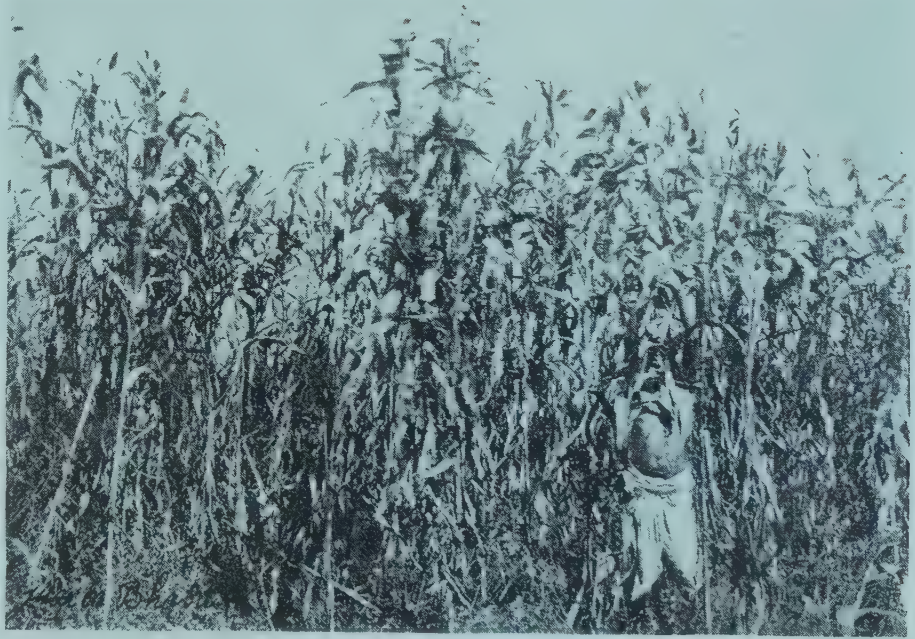

Fig. 3. JUAR ON BHATA.

whether it would not be possible to provide irrigation either by tapping sub-soil water or by constructing irrigation channels and tanks which would command such areas. Such areas undoubtedly possess great potentialities for the economic development of the agriculture of this country. At present prices the out-turn of Cambodia grown on *bhata* land last year was worth Rs. 217 per acre. The cost of cultivation, including a water-rate of Rs. 5 per acre, did not exceed Rs. 25. No manure was applied as cotton was grown in rotation with cane, for which the land had been manured the previous year.

The yields of cane obtained have varied from 25 to 40 tons per acre. The manure applied was 10 tons of sann-hemp or cattle-dung followed by a top-dressing of 1,600 lb. of *til* (sesamum) cake. The value of even 25 tons of cane when made into *gur* in the Provinces is Rs. 420. The cost of producing this *gur* (raw sugar) does not exceed Rs. 200. These are only two of several crops which have been tried and found to give, with irrigation, large and profitable yields on this porous and well-aerated lateritic soil. Most of this soil is lying waste at present. When it is cropped, as it sometimes is with *kodo*, the gross value of the crop per acre is about Rs. 10, but even *kodo* is grown on this soil only at intervals of two or three years; the land is allowed to lie fallow in the intervening years, so that the gross value of the annual yield per acre does not exceed 3 to 4 rupees. Under the climatic conditions which obtain in the Central Provinces, where we have a 3½ months' period of very heavy rainfall, from the middle of June till the end of September, at which time all our *kharif* (monsoon) crops are on the ground, the extent to which waterlogging checks the growth of these crops is very great. Soil drainage is not practised to any extent by the cultivator and he is at the mercy, in consequence, of the rainfall. We venture to say here that Mr. and Mrs. Howard of Pusa and Mr. Hole of Dehra Dun have done India a great service in focussing our attention on the importance of drainage and soil aeration as soil factors which count for even more in crop production than manuring. The time may yet come when, with the extension of irrigation facilities, these lateritic soils, which in the Central Provinces at least are at present considered to be below the margin of cultivation in most cases, will be treated as garden land of the best quality. Given water, all that is required for such soils is cultivation and manure : we can rely on nitrifying organisms to do the rest.

FOREST GRAZING AND THE NELLORE "KANCHA" SYSTEM.

BY

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THE grazing of cattle in the forest is admitted to be a detrimental practice from almost every standpoint. Apart from the injury to the forest itself, and thereby to the dependent interests, it has all the objections of promiscuous and communal grazing.

These facts and their remedies have been urged for a long time by foresters in India, but very little weight has been given to their opinions which are generally looked upon as highly coloured and biased. It is only recently, at least in the Madras Presidency, that steps towards an intelligent policy of improvement have been taken. How far this has come about through the insistence of forest officers it is difficult to judge, but it seems clear that more attention is accorded to the opinions of others on the subject. It will be useful, therefore, to quote the words of an agricultural officer who has expressed the gist of the matter more eloquently than I can hope to do. In his report on his Cattle Survey of the Madras Presidency, Mr. H. C. Sampson wrote : " It is a noticeable fact that the nearer cattle are to the forests, the more degraded the type. Here one sees all the evils of mixed grazing.......Forest grazing is always a serious menace to the forests and not only to the forests but to the water-supply of wells and tanks.......Grazing and forestry are, and must be, at variance ; for, as the forest canopy increases, the grass tends to disappear and the simplest way of lessening the shade and increasing the grass is by forest fires."

It is not necessary to dwell further on either of these two aspects of the evil.

Unfortunately, in most parts of India, at all events practically throughout Southern India, it has been customary for the people to send at least their inferior cattle to graze in the forests, and no sudden stoppage of this practice could be contemplated.

In some parts of the world some kind of compromise has been arrived at and a silvo-pastural system has been evolved under which the growing of trees and the production of fodder-grass go on side by side. But it is only a compromise and, moreover, premises the most favourable conditions of climate and human co-operation. All these circumstances are absent in India, nor could even the human co-operation be hoped for short of a considerable period ot education.

In order to devise remedial measures it is necessary to understand thoroughly the routine of the objectionable practices. Where some attention has been paid to the breeding of cattle, the breeders themselves have introduced restrictions. There the better class of cattle are stall-fed, or at least carefully segregated and grazed on the land in numbers not exceeding the feeding possibility of the area. In other localities, and in even these as far as the excess cattle maintained for manure or for the prestige of ownership is concerned, there is no such restriction. The number of cattle is far in excess of that which can find sustenance on the land. Large herds have to find what food they can, with the deplorable results inseparable from communal and excessive grazing.

To add to the disastrous position, that unsavoury enemy of vegetation, the goat, until recently was rampant. It is only within late years that this animal has been excluded altogether from Government forests.

The remedy for this state of affairs lies clearly, firstly, in the reduction of what may be termed the " drone " cattle to reasonable limits and the segregation of the different classes so as to avoid the evils of promiscuous breeding ; and, secondly, in providing ample fodder for all.

There actually has existed from before the days of the British occupation an indigenous practice of this kind in the Nellore District, and this has given a direction for the policy of the future.

The Nellore District forms a comparatively narrow belt along the Bay of Bengal, stretching for about 140 miles, starting about 40 miles north of the presidency town. On the west it is bordered by a low chain of mountains known as the Veligondas. Between this range and the sea, a distance of 50 to 60 miles, spread plains dotted with hills of gradually diminishing elevation and furrowed by numerous rivers and streams. Near the coast, and adjoining the many tanks, there are stretches of rich arable soil, but by far the greater portion of the area consists either of ocean sand, dry gravelly or quartzose soils of small fertility. A fair proportion, including most of the hillocks, is occupied by so-called forests. These are of the poorest type and are made up mostly of thorny shrubs such as *Carissa spinarum*, Randias, etc. They present ample evidence of the goat-browsing, over-grazing, and ruthless hacking of the past. Such are the areas in which the forest officers, until recently, have been inhibited from imposing salutary restrictions in the direction of limiting the number of head to the available supply of fodder, with the result that the areas have been further degraded instead of being improved after being brought under forest reservation.

It is perhaps a matter for surprise that this district is the home of the famed Nellore or Ongole breed of cattle and that so fine a breed could be raised alongside the desolation I have attempted to depict. But the best class of cattle are bred mostly in the coastal tracks where they are either stall-fed, grazed on the fields when lying fallow, or pastured on private lands earmarked for the growing of fodder under the strictest surveillance. It is only the miserable excess cattle, and of course the goats, that are responsible for the injury stated.

The areas reserved for the better cattle are enclosed within fences and are known locally as *kanchas*. They are given a period of rest during part of the year and only a strictly limited number of cattle is admitted at other times. The period of rest coincides with the time when, after the break of the south-west monsoon, the new grass is growing and the fields are not yet under crop, so that the latter are available for pasture. By the time the cattle must be driven from the fields the *kanchas* are ready for them, to be closed again when the stubble left on the fields after the harvest invites them afresh.

Owners of such grazing blocks who are in a position to admit the cattle of others demand high rates for the privilege. The fallow areas in the wet land tracts are insufficient for all the cattle when the fields are closed to them, and there sets in then a temporary emigration towards the hills, the beasts returning only after the harvest.

This is the "Kancha" System which, during the past three years, has been extended to practically all the Government forests in the plains of the district. For climatic and irrigational reasons the slopes of the Veligondas have not been included in the scheme, the hills are closed to grazing and the cutting and removal of grass alone is permitted. The plains forests have been divided up into blocks of convenient size, varying from 60 to 3,000 acres. Each block or *kancha* is put up to auction in May for the ensuing grazing season at an upset price of 4 annas per acre. As far as possible the village limits are adopted as the boundaries of the blocks so as to induce the village as a whole to purchase the lease for the use of the village itself. Here and there speculators take up a block or two with a view to making a profit on the migrant herds from the wet belt, the owners of which are willing to pay a comparatively high rate for ensured and safe pasturage of their valuable cattle.

The *kanchas* are handed over to the purchasers on the 1st July although they remain closed to grazing for another 2½ to 4 months according to seasonal variation. When grazing starts, the incidence is limited to one head of horned cattle (bulls, bullocks, cows, and buffaloes) for every two acres or one sheep per acre. It will be seen, therefore, that the grazing costs at least 8 annas per head of horned cattle or 4 annas per sheep. The majority of the *kanchas* sell for 4 annas per acre or a trifle more, but a considerable proportion, owing to local conditions and competition, fetch a good deal more, culminating in one instance at Rs. 4 per acre. This rate is in extraordinary contrast with the nominal fee of 3 or

4 annas per cow or bull, 6 annas per buffalo, and $1\frac{1}{2}$ or 2 annas per sheep, which was the grazing fee for the whole 12 months under the old system of unlimited grazing on individual permit.

From the date of opening the *kanchas* may be grazed upon until the end of April, after which they are closed again just before the first premonitory showers before the monsoon are expected. Sheep are not admitted simultaneously with horned cattle, but only after the latter have quitted late in the season.

An important feature of the system lies in the fact that the protection of the *kancha* against malpractices of all kinds is left almost entirely to the lessee, who is directly responsible and may be fined or even have the lease cancelled should he default in this matter. The lower subordinates of the Forest Department are forbidden to interfere in any way, except to assist at the direct invitation of the lessee.

With some of the blocks, in addition to the area open to grazing, the lessees undertake the protection of adjoining areas that are closed for regeneration or for other reasons. For the successful protection of these closed areas the lessee is permitted to cut and remove grass or in lieu is entitled to a rebate of one anna per acre so protected.

In recognition of their efforts the lessees whose protection has been effective, receive rewards of from 5 to 10 per cent. of the purchase price of the block according to the degree of protection extended, and the most meritorious are awarded silver medals in addition.

The lessees are provided with printed permit forms. No cattle should be found within the block without a grazier in charge and the latter must be furnished with a form signed by the lessee covering the number of animals in his care.

The eventual aim is that the leases should be taken up by the village as a corporate body and managed by an elected council or *panchayat*. In this way the people will be invested with a measure of local self-government and become the protectors of their forests and their own interests therein. Without such co-operation protection would be hopeless.

The forests open to grazing under this system are not necessarily devoted to grazing alone. Many are being worked simultaneously for the provision of fuel and small timber on a rotation by small areas. Each annually worked area, or *coupe*, is closed for a period of ten years, following the year of felling, to all grazing or extraction. Each *coupe* is surrounded by a fencing of dry thorns, which is constructed as the work of felling proceeds, so that the fence is complete by the time the produce has been removed. As a rule it is these areas that the *kancha* lessees undertake to protect in addition to the block leased for pasture.

But little reflection will make it clear that the final word has not been said when we have reached the stage described hitherto. We have seen that intensive grazing and the existence of forest growth on the same area are incompatible. Excessive grazing means the more or less rapid extinction of the trees and shrubs, while the preservation and increase of woody growth entails the gradual diminution and disappearance of grass. It follows that the management detailed cannot go on in perpetuity and further steps must be taken if a permanent supply of fodder grass is desired. Such measures are actually contemplated. The plains forests of Nellore are being classified into fuel and fodder areas according to local demands, their actual condition, and the quality of the soil.

The management of the fuel areas will continue as laid down previously, but the fodder reserves are to be treated differently. Here annual *coupes* will be felled over, but the trees left as standards will be not more than 10 per acre and will be selected for the purpose of affording shelter for the cattle against sun and rain and regardless of their qualities as yielders of timber, fuel, or other produce, so that species generally considered as quite useless from a forest point of view—for example, *Dalbergia paniculata*—may well be selected so long as they have an ample crown. The fellings also will be so conducted as to discourage regrowth by coppice shoots.

Following on the felling, operations will be undertaken for the extraction of prickly pear and other thorny growth. In the following year the seeds of good fodder grasses will be sown in the areas thus freed of thorns. The *coupes* thus treated will be closed to grazing for a period of 2 or 3 years so as to establish thoroughly the new grass.

By these operations it is hoped to evolve pure grazing areas, studded with shelter trees, capable of supporting a much larger number of cattle than at present.

In this way it is expected to achieve the objects aimed at, that is to say, the reduction in the number of "drone" cattle by limiting the incidence of grazing and raising the fees so that the best cattle get the preference, and the provision of a sufficiency of fodder for the necessary cattle. Incidentally, it will secure to Government a financial return more in keeping with the benefits provided and lead to the improvement both of the pasturage and the yield in wood, all of which is in consonance with the motto of the Forest Department: *Meliora Speramus.*

SOME OBSERVATIONS ABOUT THE SOILS OF THE NORTH-EAST INDIAN TEA DISTRICTS.

BY

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THE tea districts of North-East India comprise four large and distinct tracts of country. These are, firstly, the Brahmaputra Valley from Sadiya as far south-west as Gauhati; secondly, the valley of the river Surma which is a tributary of the Brahmaputra; thirdly, two tracts of country west of Assam, bounded by the Himalayas on the north and lying due north of Calcutta, known as the Dooars and Darjeeling Terai respectively; and, lastly, the mountainous tea district of Darjeeling proper.

The Brahmaputra Valley contains about 250,000 acres of tea. It is bounded on the north by the Himalayas, on the south and south-east by the Naga, Manipuri, Lushai, and Chittagong hills, and on the west by the hilly district between these hills and Shillong, and north of the Brahmaputra, by the district of Goalpara. The valley is widest at the north-east end, where there is a large level area, the greater part of which lies on the south bank of the Brahmaputra. The valley becomes narrower further south-west until, finally, at the western boundary of the tea-growing districts, the Jaintia and Khasi hills jut out northwards as far as Gauhati from the line of the Naga, Manipuri, Lushai, and Chittagong hills which stretch from Dibrugarh to Chittagong. The Jaintia and Khasi hills cut off the tea districts of Assam proper from those of the Surma Valley, for there is no tea grown on these hills. On the north bank of the Brahmaputra no tea is grown in the Goalpara District, which is immediately west of Mangaldai which lies north of Gauhati, and it is not until one reaches the Dooars that tea is seen again. No tea to speak of is grown in the Goalpara District for what reason I do not know; but there is no doubt that with drainage this tract would be quite suitable for tea cultivation.

The Assam Valley, the boundaries of which I have just defined, consists of level land sloping down very gradually from the hills on both sides of the valley to the Brahmaputra. In most parts of the valley the land, which is above rice field level, supports either heavy jungle, or tea, or grazing and village sites, and this land is intersected by very characteristic depressions, a few feet deep only, which are known as *hullahs*. These *hullahs* are the natural surface waterways and they run into each other, and eventually on leaving the higher ground open into large tracts of rice fields which are usually only a few feet lower than the surrounding land. These *hullahs* gradually become larger, owing partly to the denuding movement of water from the higher land, and partly to artificial broadening as they are cultivated for the growth of rice.

Near the Brahmaputra, on both sides of the valley, there are large tracts of more recent sandy alluvium which are at present covered with grass. Most of the tea in the valley has been planted on what was originally land which supported heavy jungle, but large areas of this grass land have recently been put under tea. The characteristic feature of the Assam Valley is the general levelness of the land right up to the foot of the hills, and variations of level are confined to a few feet only, except where existing rivers cut through the alluvium on their way to the Brahmaputra. No tea is grown on the hills which border the valley on either side.

In Cachar and Sylhet occur the tea districts of the Surma Valley and its tributaries, in which there are some 150,000 acres of tea. This district has several features not seen in the valley of the Brahmaputra. One is the more generally undulating nature of the land, the extreme limits of these undulations being the *tilas* or small, steeped, round-topped hills that abound all through the district. The second is that, in addition to level or slightly undulating land, there exist plateaux or banks raised by many feet above the general rice field level. These banks are particularly noticeable at the foot of the Jaintia hills in Cachar. A third noticeable feature is the occurrence of *bheels* or areas between *tilas* filled with peat many feet thick. These *bheel* soils when drained yield remarkably fine crops of tea, and the soils have particular properties which I will deal with later.

In the Dooars and the Darjeeling Terai, where, if we include that grown in the district of Darjeeling proper, there are about 170,000 acres of tea, the land slopes steeply from the Darjeeling and Bhutan hills, and in some places in the Dooars consists of a number of banks. Those which are found nearest to the hills are usually of a red, stiff loam with a deep gravelly subsoil, and are many feet in thickness. These banks are apparently absent in the Darjeeling Terai. South of these banks, or, if these banks are not present, immediately at the foot of the hills, a recent alluvial soil slopes steeply at first, and then with a diminishing gradient towards the plains. Torrential rivers break through the country at intervals along the foot of the hills, and these bring down alluvium which in many cases forms tracts of soil which differ very considerably among themselves and many of which are of special types. In this district, the rice-growing level is well to the south of the bulk of the tea-growing area, and the tea-growing area itself is made up of forest land, grazing land, and, lastly, to no small extent, of dried up or abandoned river beds, useless for agriculture. In the Dooars and the Darjeeling Terai districts, as the actual foot of the Himalayas is approached, the land rises steeply, attaining a maximum height of about 1,500 feet at the foot of the hills.

In the Darjeeling District we have the only instance in North-East India of tea estates being planted entirely on steeply sloping ground. Ghoom, near the summit of the central mountain of the district, rises to a height of 8,000 feet, and from it spurs run downwards in several directions towards the plains or towards deeply cut valleys. The flanks and faces of these spurs are very steep, and tea is planted in many places on gradients as great as 45 per cent. There is no level land at all in the district.

I think this is sufficient to explain the positions and main characteristics of the different tea districts of North-East India. The actual sites of tea estates within each of these areas have been very largely accidental and a matter of occasion. The earliest tea planters in India believed that tea should be grown on or near hills, and consequently, after tea had been discovered growing wild in Assam, the earliest experiments in putting out tea estates were made on hills or near them. Rivers were then the only means of communication. The oldest estates are found at the foot of the hills near the larger and more navigable tributaries of the Brahmaputra, though some small estates were established at a very early date at Gauhati, the only place where the hills approach the Brahmaputra.

I now turn to a more detailed account of the soils of the different districts.

In the first place, it is noticeable that, with the exception of the Darjeeling District itself, the soil of the whole of the North-East Indian tea districts is alluvial in character. The nature of the alluvium has been determined, of course, largely by the geological formations from which its material has been derived, and largely also by the conditions under which it has been deposited. I will deal first with Assam Valley.

The geological formation of the hills immediately bordering the valley on both the north and south banks of the Brahmaputra is a tertiary fluviatile sandstone, and the bulk of the alluvium of the valley has undoubtedly been derived from it. But it appears that there is an old alluvium which crops out from the newer alluvium in places, and this may be derived partly from other formations. Traces of this older alluvium are seen along the foot of the hills on the north bank, and on a tract of land covered by tea north of Tezpore. The same formation will be referred to more particularly when discussing the soils of the Dooars. The alluvium derived from this tertiary sandstone, while differing considerably from place to place according to the nature of its deposition, is yet remarkable for several distinguishing characteristics, chief among which is the invariably high percentage of fine sand, and its even composition to a great depth and over extensive areas. It is by no means a rich alluvium chemically as one would expect of a soil, in the first place, derived from sandstone; and, secondly, constantly subjected to the leaching action of rain, as is the case in Assam, where there is a high rainfall. The Assam alluvium is particularly poor in organic matter—nitrogen, phosphoric acid, and lime—but it is a soil which is naturally pervious to water, and, if the necessary run-off can be obtained and the soil is adequately drained, it affords a very fine medium for the growth of tea plants. It is sufficiently retentive of water to satisfy the requirements of the plants in the dry season, and it is easy to cultivate and maintain in a condition of good tilth.

A special study of this alluvium has been made in the neighbourhood of the Tocklai Experimental Station, our headquarters in Assam, and four definite sub-types are found to constitute the bulk of the soils of the district. In all of these, fine sand is the chief ingredient, and there is a definite gradation in quantity from fine sand through silt, and fine silt, to clay, while the amount of coarse sand varies, and this variation is chiefly responsible for the difference in type. Though this district is one in which this evenness of character is marked, other districts also which are bordered by the tertiary sandstone afford numerous examples of entirely similar soils. On the north bank of the Brahmaputra a complication arises owing to the flooding which often takes place from the rapidly moving rivers which come down through the Himalayas carrying silt derived from rocks of other kind than sandstones, and it is only owing to the fact that the rivers on the south bank carry less silt and are usually less violent than those on the north bank that this complication arises to a lesser degree in the case of the soils to the south of the Brahmaputra.

Wherever the hills bordering the plains consist of rock other than sandstone, a difference in the type of soil is immediately noticeable. A tract of country which shows this clearly is that which lies between Sibsagar and Jaipur, where the alluvium of the valley is in immediate contact with shaley and slatey rocks of the Desang series. Here some of the heaviest tea soils of the Assam Valley are situated, and a definite characteristic of the soils of this tract is the almost complete absence of coarse sand. The Nowgong District in Lower Assam contains also some very heavy soils which are derived chiefly from the Mikir hills which contain gneiss and other metamorphic rocks similar to those found in the Himalayas.

The fluviatile sandstone formation, which extends along the edge of the hills on the north and south of the Brahmaputra Valley, extends also almost uninterruptedly in a direct line towards Chittagong, and consequently the more level land surrounding the older of the low hills, or *tilas* as they are called, consists of soil very similar to that of the general sandy alluvium of Assam. The soils of the older *tilas* themselves are usually stiffer and have indications which point to their greater age. Also in the north of this district, at the foot of the hills which separate it from Assam proper, there exists a bank of heavy red soil akin to the red soils I have spoken of as occasionally cropping out in Assam and the Dooars.

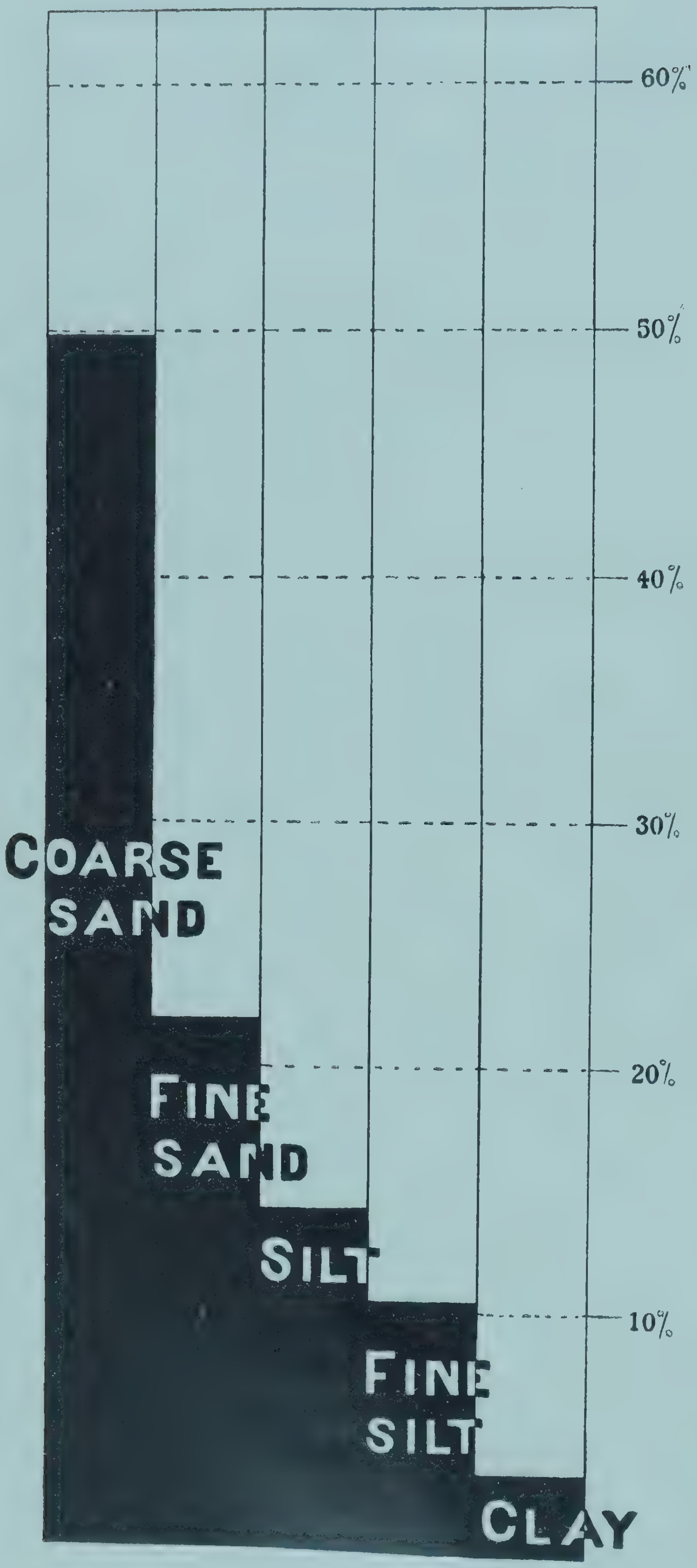
The most interesting feature of this district, however, is the existence of pockets or *cul-de-sacs* of peat soil of very remarkable depth and composition. The reason for the existence of such soils in the Cachar and Sylhet districts, and practically nowhere else, lies, I think, in the position and direction of the ranges of hills that separate the different tea-growing valleys, in relation to the line of flow of water towards the Surma and the other bigger waterways. These hills usually lie directly across the natural lines of flow of water, and consequently water backs up and collects to a much greater extent here than in Assam and in the Dooars. This, I think, accounts for the formation of peat. A hollow between two small hills is blocked at one end and water cannot find an outlet, and gradually after many years a layer, sometimes as much as 20 feet thick, of peat, or *bheel* as it is called, is formed. When such a *bheel* is first opened out with the object of planting tea, an outlet is made for the water, and a big drain, perhaps 10 or 12 feet in section, is cut, and the *bheel* is drained for the greater part of a year. When tea is planted on such soil it grows remarkably rapidly and gives a very big crop of tea per acre, which, however, is of poor quality. Ultimately, after 15 or 20 years, the *bheel* sinks by many feet, and in most cases the tea bushes then deteriorate very rapidly, though even at that stage the ultimate composition of the soil as regards percentages of total nitrogen, potash, phosphoric acid, organic matter, etc., resembles that of a very rich dung.

In the Dooars there is a broken line of tertiary sandstone along the foot of the Himalayas, but since the rivers break through this, and through the older rocks beyond it, with great violence, a very large part of the soil immediately at the foot of the hills is obviously derived from other formations.

A very much larger part of the Dooars tea districts, relatively to that of the others, is made up of the old red soils known as the Red Bank. This soil is of great depth and is characterized by being comparatively rich in coarse sand and clay, and poor in fine sand, silt, and fine silt. It is a loam, though a heavy loam, rather than a silt soil, and is capable of assuming a very fine tilth if well cultivated. These red soils are usually acid, contain very little lime, and are rather deficient in phosphoric acid, and citric acid soluble phosphoric acid is low. A very important feature of these soils is the fact that the ratio of clay to fine silt is usually high, which fact, taken with others, indicates, I think, that the soil has been *in situ* long enough to have weathered considerably.

The next most characteristic soil of the Dooars is one which, with the Red Bank soils, makes up the greater part of the whole area. This type of soil is known as the grey sandy loam, though in many cases it might be more accurately described as the grey sandy silt. Soils of very different types and ages are found among it, and are classified together more for convenience than for any other reason, for the only common feature they possess is that they have been deposited much later than the Red Bank soil. However, we can pick out some interesting sub-types, one of which is particularly interesting in connection with the most serious pest which occurs on tea estates, an insect known as *Helopeltis theivora*, commonly called the Tea Mosquito. This pest is particularly prevalent on soils of the type I am about to describe. These soils have been deposited from the rivers which come down from the Himalayas,

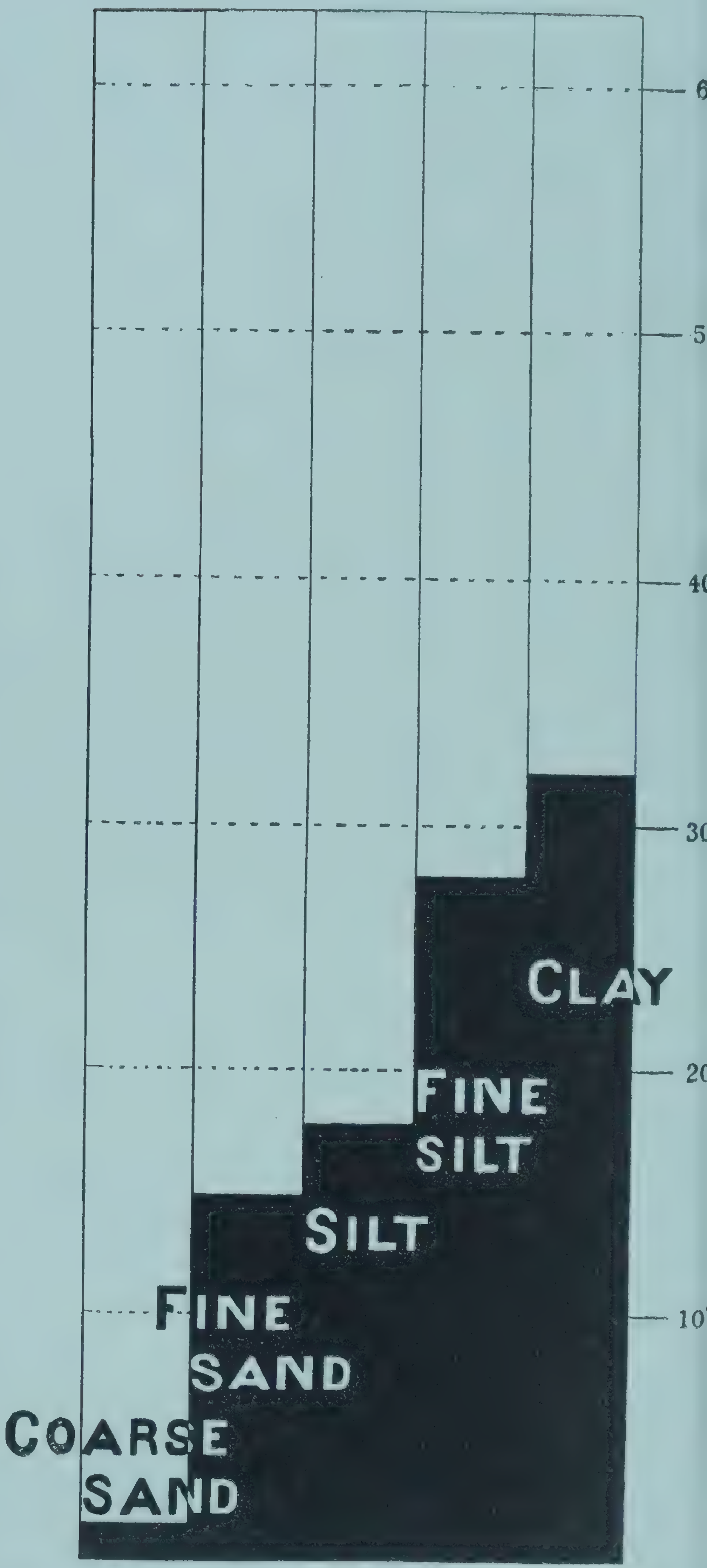
DIAGRAM I.



Scale 9′=1 inch.

Paharigoomia Tea Estate, soil marked No. C.

DIAGRAM II.



Scale 9′=1 inch.

Moheema Tea Estate, soil marked Moheema C Top.

and they consist of coarse or fine quartz sand accompanied by a large percentage of talc and potash mica. They possess fairly high percentages of phosphoric acid and remarkably high figures for citric acid soluble phosphoric acid. They are rich in potash and, curiously enough, the percentage of citric acid soluble potash is usually low, and is often present in traces only. These soils afford therefore the best illustration of an interesting fact which we have ascertained in connection with the attacks of the tea pest I have just mentioned, namely, that in a given district so small that the climatic factor may be considered uniform throughout, the attacks of the pest are less intense in the cases of estates where the ratio of citric acid soluble potash to citric acid soluble phosphoric acid is high, than in the case of estates which have soils in which the ratio is low.

Other soils belonging to the grey sandy class are actual silts, and they have large percentages of talc and other minerals which contain magnesia. Other purely sandy and still other clayey silt soils occur as sub-types.

In addition to this class of soil and the Red Bank soils there are a few others of rather special character. One particularly, derived from a carbonaceous shale, is very heavy and black in colour. The soil when damp reminds one of boot blacking. It has proved to be most unsuitable for tea.

In the Terai there is no very distinctive outcrop of the Red Bank soils, and the soils throughout are chiefly coarse and sandy, though they are stiffer further away from the hills than close under them.

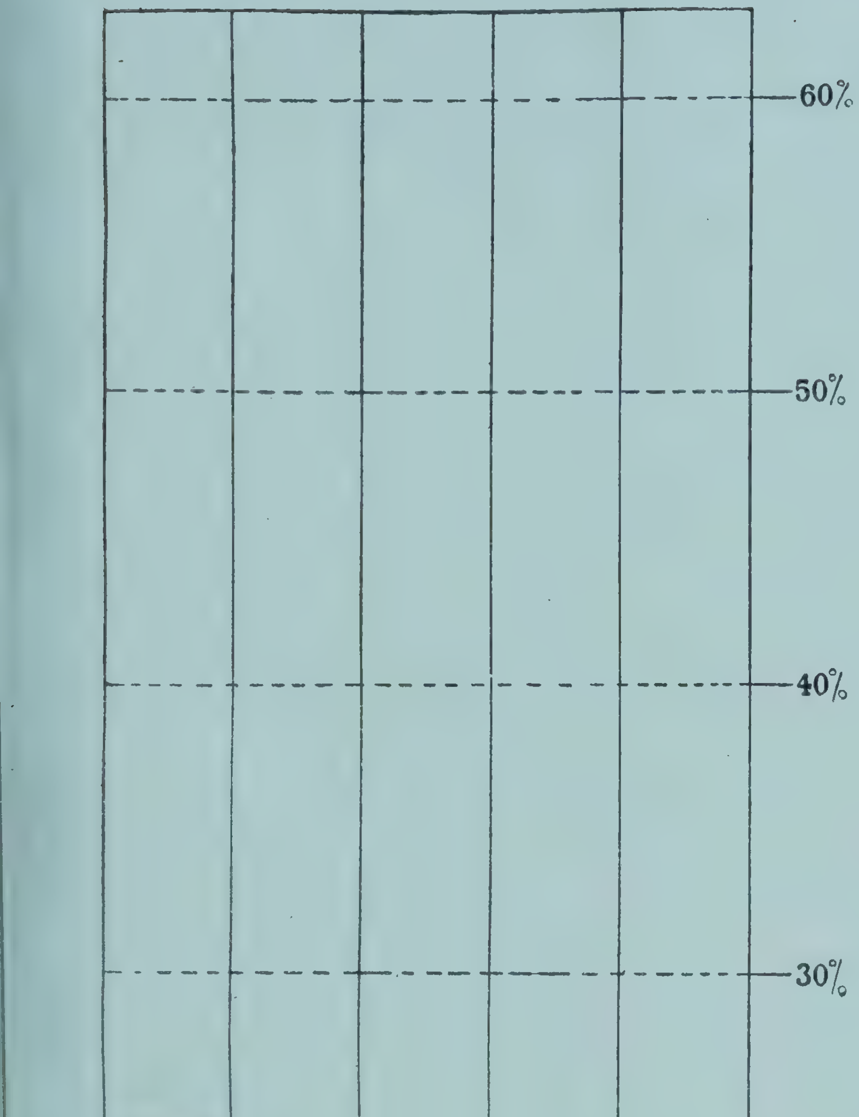
Having thus described the main features of the soils of these districts, I would like, in conclusion, to draw attention to a few special problems which are at present engaging our attention. We are making a survey of these soils, based on mechanical analyses, by a method similar to that of Hall, and I have here a few diagrams showing some of the analyses we have made. A coarse alluvial soil deposited from running water is represented by Diagram I, while a clay soil, deposited by the gradual settling of sediment after the water which brought the sediment has ceased to flow, is represented by Diagram II. Assuming that a coarse sandy soil, similar to that represented by Diagram I, is deposited, then, if the fragments of which it is composed consist of decomposable silicates as well as of quartz fragments, in process of time that part of the fine silt which consisted of decomposable silicates would be further decomposed into clay, and some of the silt into fine silt, and so on, with the result that the soil would eventually have a mechanical analysis such as that represented by Diagram III. If indications point to the soil having been originally deposited in such a way as to have a mechanical analysis grading off definitely and regularly from one direction to the other, as one would expect in an alluvial soil deposited from water, I think there is some justification for accepting an upward rise in the curves as an indication of weathering having taken place since the soil was deposited.

In the case of the soils of the Assam Valley, coarse sand seems to have been very largely eliminated when the tertiary sandstone which borders the valley was formed, and consequently the coarser soils have usually fine sand, and not coarse sand, as their chief constituent. A typical soil formed from the tertiary sandstone is given in Diagram IV. We have here to remember that a twofold deposition has taken place—(*a*) that which gave rise to the material from which the sandstone was formed, and (*b*) that which took place when the sandstone was broken down to form alluvium.

It seems probable that when a large collection of mechanical analyses have been made and studied in this way in connection with the chemical nature of the minerals composing the soil, and with the geological characteristics of the tract of rock from which these soils are likely to have come, we shall be in a better position to understand exactly how these soils have been deposited.

Another very interesting problem is in connection with the red soils of the valley. There appears to be a definite connection between the red colour of the soil and the value of the ratio of fine silt and clay. On the loamy Red Bank soils the ratio of clay to fine silt is usually higher than unity, and this, as mentioned above, presumably indicates greater age. The behaviour of the Red Bank

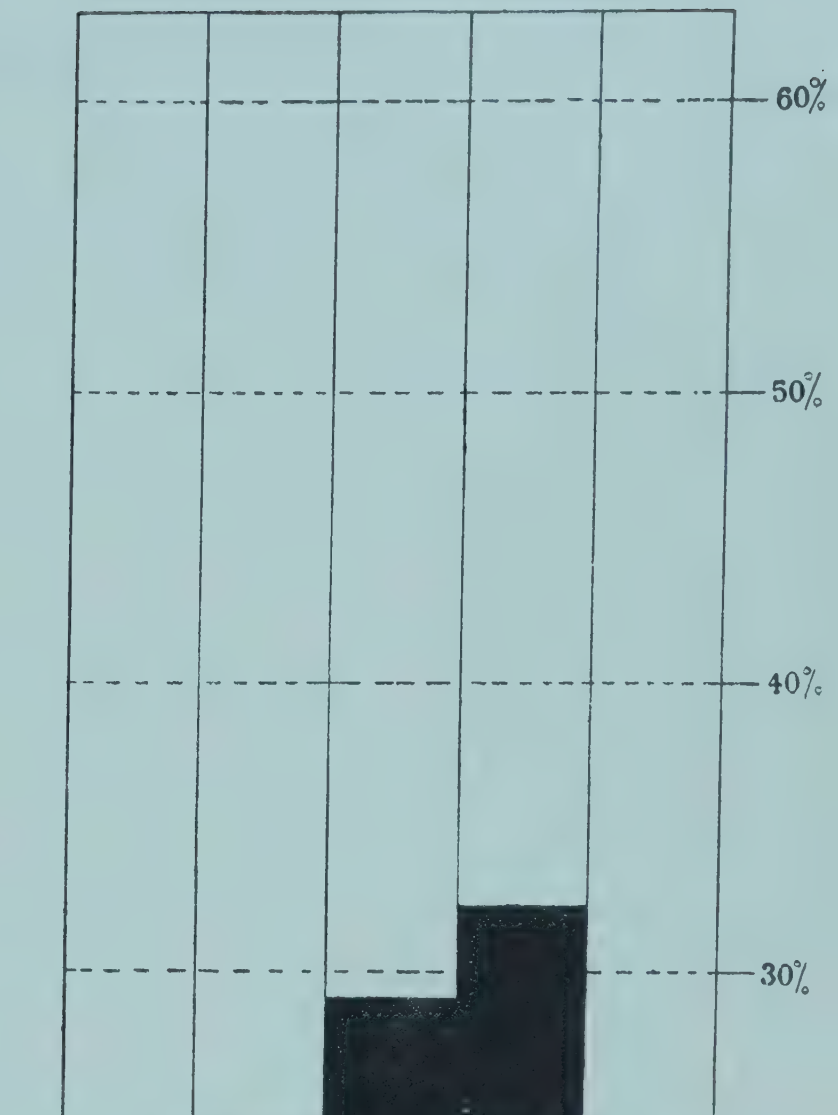
DIAGRAM III.



Scale 9′=1 inch.

Chaloni Tea Estate, soil marked 9 Surface Soil.

DIAGRAM IV.



Scale 9′=1 inch.

Rota Tea Estate, soil marked No. 10.

soils is quite different from that of other and newer soils with similar mechanical analyses, for, with reasonable cultivation, they are capable of assuming a much more excellent tilth than could be acquired by clay soils of the same mechanical composition.

A few years ago I spent some weeks in Java and was much interested in the lateritic soils that are found on the island, particularly at lower elevations. The composition of lateritic soils is there explained on the assumption that the climate alone is responsible for their formation, and the climate which brings this about most quickly and completely is one with a high rainfall distributed so that the movement of water in the soil is usually downwards, and one where the temperature is high. The geographical distribution of laterite in many parts of the world agrees fairly well with this assumption.

Now I am inclined to think that, either owing to the climate of Assam having changed and having once been wetter and hotter than it is now, or to the very long period during which these soils have been weathering in a climate which approximates to, though it does not entirely satisfy, the conditions of a climate in which laterite would be formed, these old soils have taken on a partially lateritic character, that is to say, they have broken down in weathering beyond the clay stage and contain considerable quantities of hydrated oxide of iron and alumina. I have made some experiments to determine the extent to which this has taken place in the red soils of the tea districts. The method adopted has been to determine the extent to which iron and alumina hydroxide are extracted from these and from other soils by different strengths of acid. So far as my experiments have gone (they have been conducted with samples of soil taken from 5 feet below ground in order to avoid as far as possible complication due to the presence in the soil of large quantities of organic matter) it appears that in cold hydrochloric acid of different strengths the total iron oxide and alumina removed is considerably greater than in the case of pure clay soils, but I have so far been unable to obtain any ratio of solubilities in dilute and strong acid which would enable one to pick out a lateritic from a clayey soil.

I would welcome any suggestions as to how further to investigate this problem. I start out from the definite agricultural difference which exists between the two types of soil—one red and the other grey—both having exactly similar mechanical analyses, but the red one having a very much greater possible range of tilth, and being therefore capable of behaving very much better in the field. I put down this difference between the two types of soil to the difference in behaviour of the colloidal substances in them.

There is another interesting problem in connection with the deterioration of *bheel* soils. In some cases the lack of fertility which comes after a few years in the case of soils of this class, which are still enormously rich, appears to be due to the formation of a wax which coats the particles of soil and prevents them getting wet. In other cases it is probably due to some condition affecting bacterial activities in the soil, but this I have at present made no attempt to investigate.

Finally, not to weary you with more than one other of the many problems that lie before us in connection with the tea soil of North-East India, there are certain grey sandy soils as the Dooars which contain a very high percentage of magnesia relative to lime, the ratio being in some cases as high as 14, that is to say, there are 14 times as much total magnesia as lime in the soil. In no case, however, is the ratio of citric acid soluble magnesia to citric acid soluble lime of this order, though it is sometimes as high as 2 or 3. This points to the well-known fact that magnesia has a greater tendency to combine in the form of silicates in the soil than lime has. There appear to be certain soils which have such high ratios of magnesia to lime that they are unsuitable for the growth of tea. This is a problem which I should like to investigate more carefully on the lines of investigations which have been made elsewhere as to the value of this ratio on the growth and health of other plants.

In conclusion, I hope I have succeeded in showing you that in the tea districts of North-East India we have a by no means uninteresting collection of soil types—a collection which it will well repay us to study in connection with cultivation, drainage, manuring, and other problems.

I am much impressed, and I have emphasized its importance elsewhere, with the necessity of all agricultural officers and others who are studying soil problems in India making themselves acquainted with what others are doing in the field of enquiry, and I welcome any occasion when there can be exchange of opinion and of experience.

FOREST INSECT CONDITIONS IN INDIA.

BY

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SINCE the establishment of forest research on organized lines in 1906, the work of the branch of Forest Zoology has been confined to the collection of information on the life-histories and economics of the insect pests of a few of the more valuable timber trees, and so far little attention has been paid to the question of control measures. The need for the early introduction of systematic methods for the control of the more important species has been recognized, but in Indian forests the necessity is far less urgent than that existing in other countries where systematic forestry is practised.

The insect pests of forests may be roughly grouped under three heads :—

(1) Insects which kill trees.

(2) Insects which cause loss of increment without causing death.

(3) Insects which cause technical damage to timber and forest products.

Insects of group (3), technically injurious species, are to be found wherever tree growth exists, but insects of groups (1) and (2), physiologically injurious species, are distributed with less uniformity throughout the forest tracts of the world.

The object of this paper is to attempt a comparison of the primary pests of Indian forests, *i.e.*, defoliators, bark-beetles, and heart-wood borers, with the known primary pests of other countries, but as a result of lack of data one is restricted to a consideration of forest insect conditions in the temperate regions of Europe and North America.

I. CENTRAL EUROPE.

The early development of systematic methods of forest management in the countries of Central Europe and in particular in Germany established at an early date rational lines of study of forest insects as a branch of applied entomology. Forest entomology may be said to have been created in Germany a century ago by Ratzburg and his co-workers Hartig and Nördlinger.

The insect pests of European forest trees have thus been under observation sufficiently long to furnish definite conclusions as to the types of insect damage that are normal in virgin forests on the one hand, and in forests under systematic management on the other.

The principal primary pests of Central Europe are mainly pests of coniferous forests. As is to be expected, evergreen conifers suffer far more from insect injury and especially defoliation, than do hardwoods which renew their foliage yearly and exhibit in general far greater recuperative powers.

The Nun Moth, *Liparis* (*Lymantria*) *monacha*, L., fam. Liparidæ, is a polyphagous defoliator of conifers and hardwoods. Nun Moth epidemics last generally for 5—7 years and are accompanied by the total destruction of spruce and pine forests over wide areas. The more important epidemics of the last century occurred in 1835-40 in North Germany, in 1845-67 in Prussia and West Russia, in 1889-92 in South Germany, in 1898-1901 in Sweden and Germany, and in 1905-11 in Austria, Saxony, and Prussia.

Dendrolimus pini, L., fam. Lasiocampidæ, is the most important primary enemy of the pine (*Pinus sylvestris*) ; in an outbreak, which lasted from 1862-72, some 4,000 square miles in Russia and North Germany were affected.

The Pine Looper, *Bupalus pinaria*, L., fam. Geometridæ, and the Pine Beauty, *Panolis griseovariegata*, Goetze., fam. Noctuidæ, are other dangerous defoliators of pine woods. The last looper epidemic in 1892-96 resulted in the clear felling of over 150 square miles of pine forest in Bavaria.

Fatal defoliation of beech and oak and other hardwood forests is due to outbreaks of the Gypsy Moth, *Porthetria dispar*, L., the Gold-tail and Brown-tail Moths, *Euproctis* (*Actornis*) *Chrysorrhœa*, L., and *Nygmia phœorrhœa*, Don., fam. Liparidæ.

Borers. Of bark-beetles the most important primary pest of coniferous forests is *Ips typographus*, L., fam. Scolytidæ; *e.g.*, in 1781-83 this species killed off 2½ million spruce in the Harz mountains. Severe epidemics occurred in 1862 in East Prussia and in 1868-70 in Bohemia; in the latter outbreak 400 square miles of pine forests were devastated. In 1902 some 150,000 spruce and silverfir were killed off in the Vosges mountains.

In Europe where natural regeneration of the forest is permitted only in accordance with silvicultural rules, or else regeneration is entirely artificial, one finds that young growth is subject to the attack of primary insects. Sowings, plantations, and natural regeneration areas of spruce, pine, and fir are fatally injured by weevils, *e.g.*, *Hylobius abietis*, L., and *Hylobius* spp., fam. Curculionidæ; conifers and hardwoods by cockchafer grubs and beetles, *e.g.*, *Melolontha vulgaris*, L., and *M. hippocastani*, F., fam. Scarabæidæ.

UNITED STATES OF AMERICA.

Although forest entomology is at present the least developed branch of applied entomology in the United States, yet it has shown that the very serious losses which North American forests suffer from the depredations of primary pests are controllable by simple non-expensive methods. The average annual loss due to insect damage is estimated at over £12,000,000 which is upwards of £2,500,000 annually in excess of the average yearly loss due to fires.

Defoliators. The primary pests do not include many species of defoliators. The most injurious appears to be the Large Larch Sawfly, *Nematus erichsonii*, Hartig, fam. Tenthredinidæ, which, during several extensive outbreaks since 1880, has killed off from 50 to 100 per cent. of the mature larch over vast areas in the North-eastern United States.

The defoliator of greatest local importance is the Gypsy Moth, which, introduced from Europe to the States in 1868, is now widely spread throughout eastern New England, defoliating forest, shade, and fruit trees, and agricultural crops, and entailing enormous losses and the expenditure of millions of dollars in control work. In recent years it has become established in forest areas, defoliating especially oaks, aspen, poplar, beech, limes, birch, and pines.

Bark-beetles. North American coniferous forests suffer from extensive invasions of various species of bark-beetles of the genus *Dendroctonus*, fam. Scolytidæ.

In 1890-92 the Southern Pine Beetle, *Dendroctonus frontalis*, Zimm., killed off a large proportion of spruce and pine over 75,000 square miles in West Virginia, Maryland, and Columbia. The Eastern Spruce Beetle, *D. piceaperda*, Hopk., killed off mature spruce over thousands of square miles in the forests of North-eastern Maine.

The Black Hills Beetle, *D. ponderosæ*, Hopk., has killed off in a ten-year period about a hundred million cubic feet of western pine in the Black Hills National Forest of South Dakota. The sugar pine, silver pine, western yellow pine, and lodge pole pine of the region north of Colorado and Utah, are attacked by the Mountain Pine Beetle, *D. monticola*, Hopk., and the Western Pine Beetle, *D. brevicomis*, Lec., and in direct consequence millions of feet of timber have died. In one locality in Oregon 90-95 per cent. of the lodge pole pine on an area of 150 square miles was killed off in three years. The Douglas fir throughout the region of the Rocky Mountains suffer very severely from the ravages of the Douglas Fir Beetle, *D. psendotsugæ*, Hopk.

The Hickory Bark-beetle, *Scolytus quadrispinosus*, Say., has caused the destruction of an enormous amount of hickory timber throughout the Northern and Eastern States

The hardwoods, *e.g.*, oaks, chestnut, beech, elm, etc., suffer far less from the work of primary pests, but are subject to the attacks of secondary heart-wood borers such as the timber worms, *Eupsalis minuta*, Dru., and *Lymexylon sericeum*, Harr., the carpenter worms of the genus *Prionoxystus*, and ambrosia beetles, shothole borers, and turpentine borers

CANADA.

The forests of Canada, covering an area of one and one quarter million square miles of which about 400,000 square miles contain merchantable timber, are composed chiefly of conifers. Outbreaks of primarily injurious insects occur in virgin forest on a large scale, and the need for investigation was recognized by the appointment of a forest entomologist in 1911.

Defoliators. Of the defoliators the most important pests are the Large Larch Sawfly, *Nematus erichsonii*, Hartig, fam. Tenthredinidæ, the Spruce Bud Worm, *Tortrix fumiferana*, Clem., fam. Tortricidæ, the Brown-tail Moth, and the Pine Butterfly, *Neophasia menapia*, Felder.

The Large Larch Sawfly during the last 20 or 30 years has shown itself to be a serious pest of the larch (*Larix americana* and *Larix* spp.). In 1881-86 it killed off by repeated defoliation practically all the mature larch in Eastern Canada : outbreaks occurred again in 1894-98 and 1903-06. Considerable damage has been inflicted by the Spruce Bud Worm to the balsam and the spruce, especially in the eastern regions of Canada, and to the Douglas fir (*Pseudotsuga douglasii*) in Vancouver Island.

Canadian forests of both coniferous and broad-leafed species (oak, elm, and maple) are threatened also by the Brown-tail Moth, which appeared 12 or 15 years ago and is now endemic in the transition zone of Nova Scotia, and epidemic in the boreal parts of New Brunswick. There is every possibility, if the insect becomes established, of its being a serious pest throughout the transition zone of the Dominion.

Borers. The destruction caused by defoliators is slight compared with that due to the depredations of bark-beetles of the genus *Dendroctonus*. What has been said about these species in the Rocky Mountains and the Pacific Coast region of the United States holds for corresponding regions in Canada. The tree species suffering most seriously are *Pinus ponderosa*, *P. monticola*, *P. murrayana*, *Pseudotsuga mucronata*, and *Picea sitkensis*.

It must, however, be noted that the three most injurious defoliators of North America and Canada are not indigenous species but introductions from Europe.

II. British India.

There are 250,000 square miles of forest in India and Burma, of which 108,000 square miles are under more or less systematic management, but in at least half of this area we have little idea of the rôle played by insect pests or even if economically important pests exist. Although some 55,000 square miles of forests are managed under Working Plans at the present time, we have not as yet brought into force methods to ensure the systematic record of damage due to insect pests, nor are we able to calculate the value of the annual loss due to any one species. The data available, however, show, even in a rough comparison, that well-marked differences occur between forest insect conditions in India and those in other parts of the world.

Defoliators. Of defoliators in coniferous forests India appears to have no species that correspond to the sawfly and lasiocampid caterpillars of North America and Europe. The Himalayan pines, silver firs, spruce and deodar, and the evergreen oaks of the mountain forests are (so far as any records are available) entirely free from primary defoliation with fatal results.

Of the hardwoods several species of lepidopterous defoliators are known and widespread. In deciduous forests the teak, *Tectona grandis*, is defoliated periodically, and frequently annually, throughout the whole of its distribution by two species, *Hyblæa puera*, Wlk., fam. Noctuidæ, and *Pyrausta machæralis*, Cram., fam. Pyralidæ, and several species of Arctiidæ, but no case of fatal defoliation sufficiently extensive or prolonged has been recorded which would cause these species to be considered as primarily injurious insects. Complete defoliation of teak is followed by a rapid renewal of the crown foliage or by temporary production of epicormic shoots. The injury is thus restricted to loss of increment and occasional stagnation.

The sal, *Shorea robusta,* is defoliated by numerous species of Lepidoptera most of which appear in groups or associations, *e.g., Dasychira thwaitesi, D. horsfieldi, D. mendosa, Lymantria ampla, L. bivittata, L. semicincta* which defoliate hundreds of square miles of sal forest in the eastern parts of its range. The earliest record refers to an attack in 1884 in which 200 square miles of forest north of the Brahmaputra river were completely defoliated. *Trabala vishnu,* Lef., *Suana concolor,* Wlk., fam. Lasiocampidæ, *Ingura subapicalis,* Wlk., fam. Noctuidæ, and other species periodically defoliate the tree in the Central Provinces and in the United Provinces.

Almost every timber species of importance in the deciduous and evergreen forests supports a series of lepidopterous and coleopterous defoliators and pruners, nevertheless in the above-quoted instances, and in the arid-country and littoral forests where pests have been less extensively studied, there is a complete absence of epidemics which have resulted fatally to the forest as a whole or to all the individuals of one tree species in the forest.

Borers. The Himalayan conifers are attacked by species of bark-beetles generically allied to those of the European and American conifers, *viz., Ips, Polygraphus, Cryphalus, Scolytus. Ips longifolia,* Steb., is the most destructive pine bark-beetle throughout the zone of *Pinus longifolia* and *Pinus excelsa.* The deodar (*Cedrus deodara*) is attacked by species of *Scolytus*, a genus which is confined to broad-leafed trees in European and American forests. Under normal conditions the bark-beetles are not primary pests, but a few instances occur in which appreciably large areas of forest have been devastated by epidemic outbreaks, *e.g.,* in 1903-06 in the forests of *Pinus gerardiana* in Baluchistan by *Polygraphus trenchi,* Steb. ; in 1908-10 in deodar forests in the Simla Catchment Area by *Scolytus major,* Steb. ; and in *Pinus longifolia* forests in the United Provinces in regeneration areas and following on serious fires by *Ips longifolia,* Steb. The case of primary outbreaks of *Ips longifolia* in regeneration areas of chir pine is a habit of recent development and hardly to be considered as normal, as it is associated with the changes in forest management which favour the concentration of regeneration operations and consequently of breeding grounds for the insect. Other apparently primary activities of the Pine Bark Beetle in plantations have recently been shown to be consequent on previous attack by bark blister fungi. Bark-beetles of timber species in deciduous and evergreen forests are, in all observed cases, undoubtedly of secondary origin. The species of *Sphærotrypes* and other bark-beetles which breed in *Anogeissus latifolia, Terminalia tomentosa, Shorea robusta,* and other *Dipterocarps* do not successfully attack living healthy trees.

Shothole and pinhole borers, fam. Scolytidæ and Platypodidæ, represent a class of borers which are characteristic of Indian forests, as also of most tropical and semi-tropical forests, and which are comparatively absent from European and North American forests. Conifers and oaks in the mountain forests and practically every timber species of economic importance in the deciduous and evergreen forests are subject to attack by shothole and pinhole borers. The sal, for example, serves as breeding material for at least 27 species of *Xyleborus, Progenius, Diapus, Platypus, Crossotarsus,* etc. As far as the writer's observations go they are all to be classed as pests of secondary importance; the technical damage done is very considerable, but the attack is confined to dying and unhealthy trees. In 1911-14 considerable mortality in the sal forests of Bengal was assigned to *Diapus furtivus*, Samps., fam. Platypodidæ, until investigation showed that the species was present in only 16 per cent. of the dead trees, and that the shothole borer attack was secondary to that of a root parasite, *Polyporus shoreæ.* Again in the Sunderbans forests of Sundri, *Heritiera Fomes*, an epidemic outbreak of *Crossotarsus squamulatus*, Chap., fam. Platypodidæ, which occurred with all the appearances of a primary outbreak, was found to be limited to trees possessing diseased roots. Heart-wood borers of the families of Cerambycidæ and Lamiidæ (Coleoptera), and Cossidæ and Hepialidæ (Lepidoptera) are common pests of the more important trees, but it is doubtful if any are normally capable of killing off forests over large areas. The teak during the first few years of its life is attacked by a lamiid, *Haplohammus cervinus*, Hope, and the hepialid *Phassus* *malabaricus,* Hmps., which produce cankerous and distorted growth in young saplings with galleries in the heart-wood. Young *babul* (*Acacia arabica*) is attacked by a lamiid, *Cœlosterna scabrator,* F., while numerous other trees now grown in plantations show similar attacks in the sapling stage. In plantations of these trees repeated attacks are often serious enough to cause the death or stagnation of a large proportion of the crop, but under natural conditions the activities of the pest have never been sufficiently conspicuous to cause comment.

The sal is not attacked by heart-wood borers in its youth but trees over 2 feet in girth suffer serious technical damage from the larvæ of *Hoplocerambyx spinicornis,* Newm., fam. Cerambycidæ. Normally this species breeds in dying or diseased trees. Under abnormal circumstances it may assume the character of a primary pest, but its rate of increase and dispersion is so slow that it can be easily controlled. In those Bengal and Assam sal forests where a generally unhealthy condition of the soil prevails, the proportion of dead trees infested by *Hoplocerambyx* has not exceeded 40 per cent. in an observed period of three years, although the borer is endemic in the area. In a recent local outbreak of this species in United Provinces sal forests the number of living trees infested in the sixth year of the attack is less than 30 per cent. of the whole crop, and the area affected under 2,000 acres.

The teak is attacked from the young pole stage to the end of its life by a serious pest, the beehole borer, *Duomitus ceramicus,* Wlk., fam. Cossidæ. The heart-wood of the living tree may be riddled with galleries an inch in diameter without affecting its vitality ; in fact the average teak tree reveals nothing of the activity of the beehole borer until it reaches the saw mill.

Numerous other illustrations might be cited to show the absence in the forests of India of a primary insect pest which is capable of killing off vigorous healthy trees, or of devastating virgin forests over a large area. The principal pests of natural forests are purely of secondary importance, normally breeding in unhealthy or newly killed timber, and incapable of successfully attacking healthy trees. But it should be understood that the species in question are of secondary importance only in respect to their directly fatal powers. As causative agents of serious technical damage to timber, of loss of increment, of stagnation and malformation, they are admittedly of primary importance, and in this respect undoubtedly stand as high as the secondary pests of other countries.

This condition of inter-relationship between insect species and their hosts would appear to be normal on the one hand in strictly virgin forests, and on the other hand in ravaged forests which under protection are resuming a stable condition approaching the primitive. Conditions outwardly similar prevail, as far as it has been possible to ascertain, in the forests of the Dutch East Indies, the Philippines, East and Central Africa, and the northern coastal belt of Australia.

The past methods of forestry in India have not favoured the development of forest insects to the stage of primary pests. The retention of the normal distribution and proportion of tree species in the growing stock prohibits extraordinary increase of defoliators, while the methods of timber felling and extraction do not provide facilities for abnormal breeding of borers.

As the majority of the forests now worked in India are irregularly stocked as regards species and age classes, and felling operations are carried out by the selection of small numbers of trees over large areas—a method which reproduces natural conditions more exactly than other silvicultural methods—an abundance in any one locality of loppings, slash and unconverted portions of logs which serve as breeding grounds for borers is avoided. Moreover, extraction of the timber usually takes place within a few months of felling and at a period when the imaginal activity of the pest is lowest.

The objects of forest management in the future, however, do not tend towards the maintenance of the forest in its primitive natural condition but rather towards the elimination of economically worthless species, and the production of more uniformity in distribution and age of the valuable species. In several divisions already Working Plans are in force which are converting the original irregularly stocked forest into an artificial type of forest consisting of a series of even-aged crops with an increased proportion of the economically valuable species.

In forests of the uniform type fellings and regeneration operations are more concentrated both in time and in place and the danger of abnormal insect activity is thereby increased. It is in these forests and in our artificial regeneration areas and plantations that we may expect in the near future to find the existing secondary pests assuming under epidemic conditions the rôle of primary pests. But at the same time it is in these forests that control measures can be introduced on a scale more practical and efficient than at present possible.

EXPERIMENTS IN PLANTING SUGARCANE SETS WITH A SINGLE EYE-BUD AND POT EXPERIMENTS WITH OTHER SEEDS PLACED IN DIFFERENT POSITIONS WHILE PLANTING.

BY

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THE writer has been carrying out some experiments at the Government farm, Dharwar, on the effect which sowing or planting seed in different positions in the ground has on the subsequent growth of the crop. As the preliminary results are encouraging they are given below :—

Sugarcane. The usual method of planting sugarcane at Dharwar is to plant sets with three or four eye-buds in furrows, with irrigation water given in the furrows before planting. The sets are put in, in rows by hand, and are often trampled under foot, and thus buried in the wet soil. By doing so, the eye-buds are placed in different directions in the ground, some pointing upwards, some on the sides, and some downwards. The buds that are on the top of the sets germinate early, those on the sides later, and those at the bottom die out altogether. Thus the sets produce a smaller number of plants than they are capable of, giving also uneven germination. To avoid the latter, an experiment was conducted on the Dharwar Farm, in small beds in the first year, and on a field scale in the second year (current), of planting sets, cut so as to contain only one eye-bud each, that eye-bud being placed upwards. The experiments have been successful in both years in the following points :—

(*a*) Sets with a single eye-bud, planted as described above, have given a higher percentage of germination than in the local method of planting. The germination in the single eye-bud method was above eighty per cent.

(*b*) The germination in the case of the single eye-bud method was earlier by one week, and all the plants germinated simultaneously. Thus a uniform crop has been secured.

(*c*) The eye-buds being placed upwards, the plants go straight up, and if planted deep, there is less liability of the cane lodging when grown up, and also there is greater facility for work between the rows, *viz.*, interculture and earthing up, etc.

As there is very high percentage of germination of the eye-buds originally planted by this method, there is no necessity of allowing subsequent tillers to grow into canes. Thus in the single eye-bud method, all the tillers are removed, and only the mother canes are allowed to develop. Hence all the manure given becomes available to the mother canes only, and consequently they develop into long thick canes of uniform age, and ripen all at the same time, by which a higher percentage of sugar is expected than in cases of uneven age at harvest time.

By the method described above, the writer has got above 32,000 canes per acre of good size, the average weight of each cane being about five pounds. The crop is yet standing, and the actual weight of canes cannot be given until it is harvested. A few canes have, however, been weighed, and the weight has been between four and six pounds. Thus it is expected that the yield under the single eye-bud system of plantation would be above 130,000 lb. of cane per acre.

The photographs opposite (Plate VIII) will give an idea of the uniformity of the crop, *viz.*, height and thickness of the canes without any tillers.

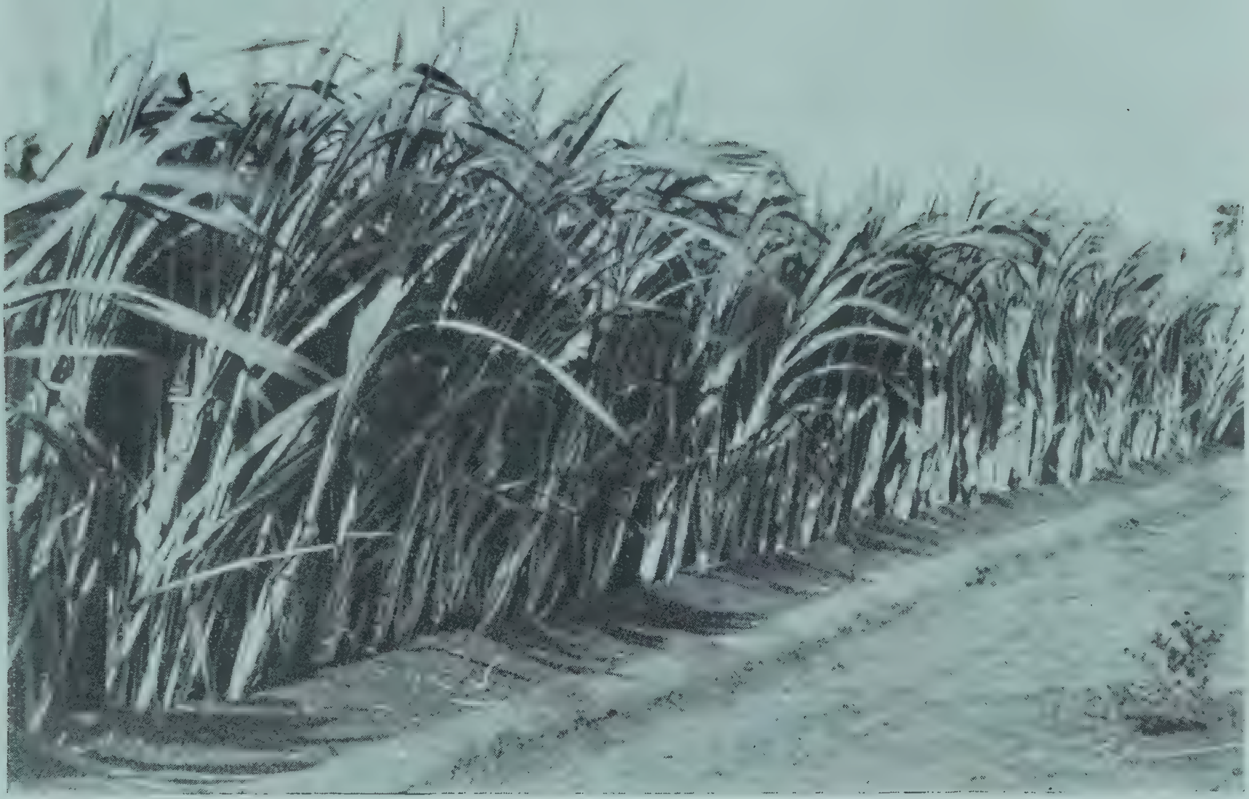


Fig. 1. Side view of the sugarcane rows grown with single eye-bud sets.

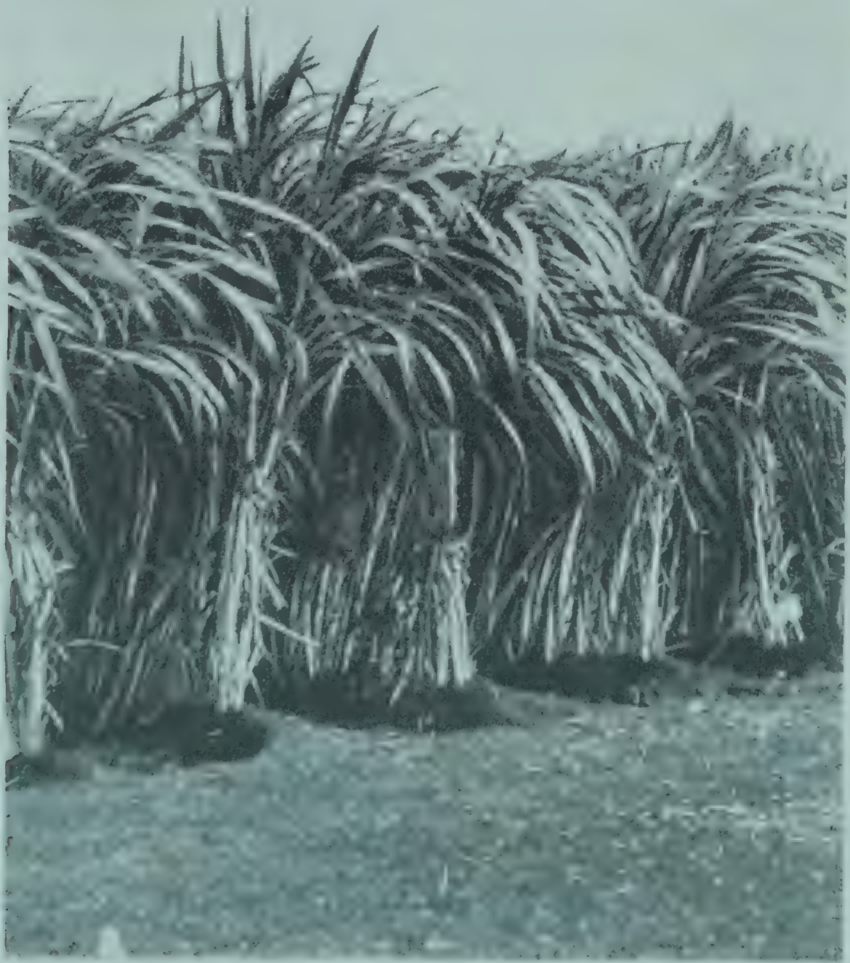
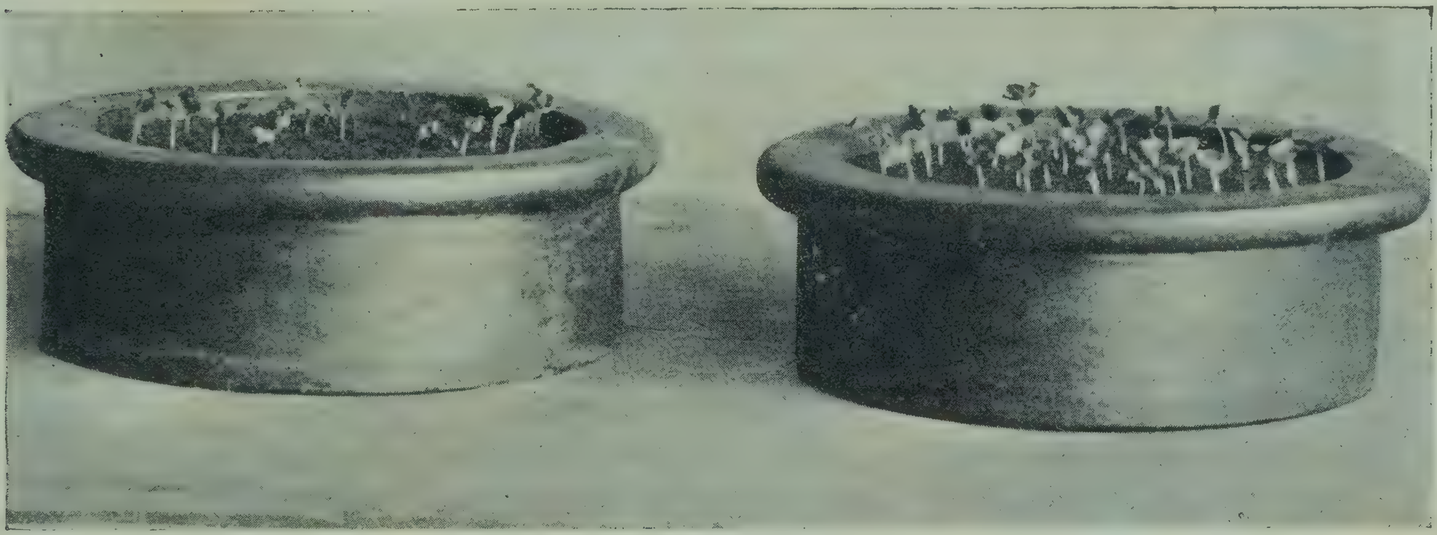


Fig. 2 Front view of the sugarcane rows grown with single eye-bud sets.

Cotton. Seeds planted with the apex upwards germinated earlier than any others, while those with the apex downwards germinated later, and those with the apex sideways came up last. The great peculiarity in the seeds planted with the apex upwards was that the seed coat entirely remains in the ground, while in the two other cases the seed coat is brought up by the plumule. The young plant is hindered in its development by the fact that it has to carry the seed coat up with it through the soil, and it is some time before it gets rid of the encumbrance. The result is that there is a marked difference between the length of time taken by the plants to appear above ground, to allow the cotyledons to open fully, and to acquire a green colour; the plants from seeds put in with the apex upwards always appearing first and getting a better start.



COTTON.

Apex down plants with seed-caps on the cotyledons.

Apex up plants without any seed-caps on the cotyledons.

Cereals. The seeds tried were *jowar* (*Andropogon Sorghum*) and wheat. In these cases, seeds planted with the apex sideways germinated earlier than those in which the apices were placed upwards or downwards. The seeds with apices upwards were earlier than those with the apices downwards.

Leguminous plants. (1) *Sann* (*Crotalaria juncea*) was tried as it was considered to be one of the most quickly germinating seeds we have. In this case the seeds with the apices downwards germinated first, while those planted with the apices upwards germinated before those planted sideways.

Unlike cotton, the seed coat was brought up by the plumules in all the three methods of planting.

(2) *Gram* (*Cicer arietinum*). In the case of gram the seeds placed sideways and upwards germinated simultaneously and fully earlier by one day than those whose apices were placed downwards.

There are many seeds whose shapes are such that, when sown, they naturally fall in the ground only in certain positions. Among such seeds are wheat, rice, linseed, and *sann*. It may be for this reason that these crops are seen to give, on the average, a much more even stand in the fields than many other crops, such as *jowar*, maize, gram, cotton, *tur* (*Cajanus indicus*), etc., whose rounded shapes make them fall at random in the ground, and consequently leads to a greater unevenness in the subsequent crop.

Similarly, some of our garden crops which are grown by planting sets with the eye-buds upwards, or in any particular direction, are even in growth. The most striking example of these is *suran* (*Amorphophallus campanulatus*). In this case sets of uniform age with uniform eye-buds are planted at a uniform depth with all the eye-buds placed upwards, with the result that all plants germinate simultaneously and grow to a uniform height. Sets of potatoes and turmeric, if selected with uniformity in the development of eyes while planting, give the same results. Thus there is evidence that the position of the seed in the ground while planting is an important factor in obtaining a uniform crop. Experiments are being continued, and the figures on which the present notes are based will shortly be published.

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